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COMPUTER MODELLING OF THE UK WIND ENERGY RESOURCE: UK WIND SPEED DATA PACKAGE AND USER MANUAL

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AEA Industrial Technology
Harwell Laboratory

prepared by

S. F. Burch and F. Ravenscroft

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ABSTRACT

A software package has been developed for IBM-PC or true compatibles. It is designed to provide easy access to the results of a programme of work, funded by the UK Department of Energy, to estimate the UK wind energy resource. Mean wind speed maps and quantitative resource estimates were obtained using the NOABL mesoscale (1 km resolution) numerical model for the prediction of wind flow over complex terrain. NOABL was used in conjunction with digitised terrain data and wind data from surface meteorological stations for a ten year period (1975-1984) to provide digital UK maps of mean wind speed at 10m, 25m and 45m above ground level. Also included in the derivation of these maps was the use of the Engineering Science Data Unit (ESDU) method to model the effect on wind speed of the abrupt change in surface roughness that occurs at the coast.

With the wind speed software package, the user is able to obtain a display of the modelled wind speed at 10m, 25m and 45m above ground level for any location in the UK. The required co-ordinates (Ordnance Survey Easting and Northing) are simply supplied by the user, and the package displays the selected wind speed.

This user manual summarises the methodology used in the generation of these UK maps and shows computer generated plots of the 25m wind speeds in 200 x 200 km regions covering the whole UK. The uncertainties inherent in the derivation of these maps are also described, and notes given on their practical usage.

Existing isovent maps, based on standard meteorological data which take no account of terrain effects, indicate that 10m annual mean wind speeds vary between about 4.5 and 7 m/s over the UK with only a few coastal areas over 6 m/s. The present study indicated that 23% of the UK land area had speeds over 6 m/s, with many hill sites having 10m speeds over 10m/s. It is concluded that these 'first order' resource estimates represent a substantial improvement over the presently available 'zero order' estimates. The results will be useful for broad resource studies and initial site screening. Detailed resource evaluation for local sites will require more detailed local modelling or ideally long term field measurements.

COMPUTER MODELLING OF THE UK WIND ENERGY RESOURCE:

USER MANUAL FOR UK WIND SPEED DATA PACKAGE

CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

1. INTRODUCTION

Accurate estimates of wind speeds within the UK are important for many purposes including the assessment of structural safety and the assessment of sites for wind turbine generators.

Existing wind speed data for the UK are limited primarily to isovent maps, derived from long term measurements of hourly mean wind speeds by the Meteorological Office. However, these maps take no account of terrain effects, (meteorological stations are generally sited in flat and open regions such as airfields, and are widely separated). Since energy in the wind is proportional to the cube of the wind speed, the effect of terrain on local wind energy availability (and therefore on the cost of wind-generated electricity) can be dramatic.

Considerable international effort has been put into development of computer models to quantify wind flow over complex terrain. A Pilot Study [1] was carried out by Harwell Laboratory in conjunction with ETSU and ERA Technology, within the Department of Energy Programme, to evaluate the use of one of these models (NOABL) for resource assessment in the UK. A comprehensive methodology was developed to provide estimates of annual extractable wind energy over a 100 x 100km test region in SW Scotland. In spite of uncertainties inherent in the technique, the study concluded that the approach provides a relatively simple and inexpensive method for wind speed and resource estimation and site evaluation - which is considerably better than existing data for hilly regions of the UK. The present programme has extended the Pilot Study approach to the rest of the UK, and produced maps of wind speed and extractable energy on a 1 km grid (see [2] a for full explanations of the derivation of these maps). These maps have subsequently been further refined by modelling the effects on wind speed due to the abrupt change in surface roughness that occurs at the coast, using a method described in Appendix 1.

To enable ready access to be gained to the results of this programme, a wind speed software package for an IBM-PC or true compatible has been developed. This simple package enables the wind speeds at 10m, 25m and 45m above ground level to be displayed for co-ordinates (Ordnance Survey easting and northing) supplied by the user. The maps accessed by the wind speed package provide an objective baseline for resource estimates and initial site screening.

Details of the NOABL programme and the methodology developed to apply the model to resource estimation have been given in [2], and Appendix 1. The approach is summarised here in Section 2. The uncertainties inherent in the derivation of the maps and comments on their practical usage are given in Section 3. Section 4 shows displays of the UK wind speed map for 25 m above ground level for eighteen 200 x 200 km regions covering the whole UK. A user guide covering the operation of the wind speed software package is given in Appendix 2.

2. THE METHODOLOGY FOR MODELLING OF MEAN WIND SPEEDS

2.1 Wind flow model

The validity of wind flow models has been the subject of a study by the IEA [3]. Results indicated that for individual points, the accuracy of all models considered was relatively low ($\pm$ a few m/s), but that nevertheless models with resolution 1-2km can be useful for broad resource assessment or initial site screening. In these applications, the simplest models do considerably better than the others for the normal situation where crucial data needed to run the more sophisticated (and expensive) models are not available.

On this basis the relatively simple objective analysis model NOABL (developed by Science Applications Inc., USA) was chosen for the present study. Such models do not make use of the equations of motion or energy conservation, so thermal and other more complex effects are not included, but they have considerable advantages in numerical stability and computing requirements. The validation reported in the IEA work showed that NOABL is suitable for describing the general flow when the dominant mechanism forcing the flow is the gross effect of topography. This is similar to the requirement for atmospheric neutrality and means that the model performs best for strong wind conditions - which contribute most to wind power.

The NOABL programme requires wind speed and direction data for one or more points within the modelled region, and then follows a procedure of interpolation to determine an estimated three-dimensional wind field on a specified finite difference grid. This initial wind field is then adjusted iteratively to account for terrain effects and atmospheric stability considerations, constrained by the condition that the resulting wind field be non-divergent. The model can use wind data from a number of surface stations within the model region, and if detailed upper air data are available these can be used as well. Newton and Burch [1] considered different initialisation strategies using surface data (from meteorological stations) and concluded that use of a single station for initialisation provided the optimum approach (single and multi-station initialisation gave similar results for strong wind conditions which contribute most to the resource, and the implications of multi-station initialisation would lead to prohibitive computing costs).

In principle, the 900 mb wind should be a good approximation to the free stream wind, and the data less affected by local surface roughness, flow disturbances from nearby buildings etc. which can affect the standard low level measurements very significantly. However it was recommended [1] for a number of reasons that in practice the best approach was to establish a well sampled network of reliable surface stations, minimising as far as possible local effects on the anemometer measurements.

The NOABL model provides an instantaneous prediction of the wind field within the terrain region to which it is applied, on the basis of the wind speeds and directions of the meteorological station(s) used for initialisation of the model. As described in Section 2.2 below, the present programme used these *instantaneous* predictions as the basis for estimating *mean* wind speeds over a ten year period across the whole UK. This was achieved by adopting initialisation based on a single meteorological station only. For single station initialisation, the modelled wind speeds provided by NOABL are directly proportional to the initialisation wind speed. Furthermore, for single station initialisation, the NOABL predictions have a 180 degree symmetry, so that the twelve direction intervals (wind direction data can be adequately represented by 30 degree direction 'bins') can be covered by only six different NOABL runs. With the output from these six NOABL runs, it is therefore possible to predict the wind speed and direction at any point within the modelled terrain region, for any arbitrary initialisation wind speed and direction at the location of the meteorological station.

2.2 Summary of the methodology

Newton and Burch [1] showed how the NOABL model, and hourly wind speed and direction data from long term meteorological observations, can be combined to estimate the distribution of mean wind speeds over complex terrain in regions of order 100x100 km in size. Validation of the procedure showed that the results were internally consistent and the predicted variations corresponded qualitatively to those expected.

Burch et al [2] described, in detail, the application of this approach to a set of 56 regions covering the whole UK, and the subsequent combination of the results from the individual regions into single maps of the whole UK. The positions of these 56 regions are shown in Fig. 2.1, and further details are given in Table 2.1. The maps have subsequently been further refined by modelling the effect on wind speed of the abrupt change in surface roughness at the coast. For each terrain region (120 x 120 km) to be covered by runs of the NOABL model, the following sequence of calculations was carried out:

1. For the meteorological station within the region, histograms of observed wind speeds were derived in each of twelve 30 degree direction intervals.

2. The NOABL program was run for each region, at intervals of 30 degrees in wind direction at the initialisation station (only six NOABL runs were needed for each region, due to the 180 degree symmetry of the model).

3. From the NOABL output maps, the speed-up factors relative to the initialisation site were calculated for each grid point and direction interval at each height above ground level.

4. The NOABL speed-up factors at each height above ground were modified to allow for the change in surface roughness at the coast using the ESDU method.

5. Corrections were made for local surface roughness effects and also for any difference from 10m above ground level in the effective height of the wind speed data from the meteorological station.

6. All hourly wind speed data were summed over to generate a wind speed histogram, and mean wind speed at each grid point for 10 m height above ground level.

7. The results were vertically extrapolated to 25m and 45m heights above ground level (the assumed hub heights of the MS3 and LS2 wind turbines, respectively).

8. Account was taken of wind turbine characteristics to derive the 'theoretically extractable' annual mean power output for each grid point.

The maps of mean wind speed and extractable power, derived independently for each of the 56 regions, were then assembled into complete datasets, covering the whole UK. The method devised for deriving these integrated UK maps is described in detail in [2]. Essentially, an iterative method was used to adjust uniformly all the wind speeds in each region to match those of neighbouring regions (the network of regions had extensive areas of overlap so that comparisons were made in these areas of overlap). This procedure was successful in generating a single UK map in which the 'joins' between the individual regions were hardly apparent. To achieve this result, the wind speeds in individual regions had to be scaled by the factors given in Table 2.2, which for 25 m height varied between 0.73 and 1.33 (standard deviation of 0.12).

2.3 Selection of regions for NOABL modelling

To minimise boundary effects, the NOABL program was run on regions of 120 x 120 km in size, and use was made of the data from the inner 100 x 100 km area.

A network of suitable meteorological stations was established in conjunction with the University of East Anglia Climatic Research Unit and the corresponding locations of the 56 regions for NOABL modelling were defined using the following rules:

1. Regions should overlap by at least 10% in area.

2. The meteorological station used for initialisation of the NOABL runs should be as near the centre of the region as possible, and in any case more than 10 km from the edge of the 100 x 100 km boundary.

3. Some regions should contain two meteorological stations to enable comparison for validation purposes.

With the exception of a few regions which needed small modifications in size, it was possible to provide complete coverage of the UK in this way using the 56 overlapping regions shown in Fig. 2.1 and Table 2.1.

The NOABL methodology was applied to all the 56 regions, so that complete digital maps could be provided on the same basis for the whole UK.

2.4 Vertical wind speed extrapolation

It is necessary to extrapolate vertically the meteorological data, which are generally measured at 10m above ground level (AGL), in order to obtain wind speeds at the WTG hub heights of 25 and 45 m above ground level. In the lowest few hundred metres the variation of wind speed with height in a flat region of terrain is affected by friction at the surface. An empirical power law is often used to approximate this boundary layer profile:

$$V_z/V_{z1} = (z/z1)^{1/\alpha} \qquad (2.1)$$

where V_z is the wind speed at height z. The value of the power law exponent depends on factors such as local surface roughness (see Section 2.5, below), wind speed and atmospheric stability [4] as well as meso-scale terrain dependent effects.

On initialisation of the NOABL wind flow model, the vertical scaling of wind speeds within the boundary layer was determined by a power law profile, with a constant exponent chosen to be 1/7 = 0.143, as used previously [1]. After iteration, the predicted wind speeds in each vertical column of mesoscale cells will depend on the local terrain. The exponents in areas of high terrain gradients will be lower, on average, than those in flat regions. Thus, as expected, the modelled wind speeds at higher heights AGL are less strongly influenced by the terrain than those speeds at lower heights AGL.

The three-dimensional NOABL output itself is used for the vertical extrapolation of the meteorological station wind speeds to the required heights AGL of 10, 25 and 45 m. This is done by calculation of speed-up factors relative to the initialisation station for the required grid points in the NOABL output. The resulting speed-up factors at fixed height AGL are then combined with the wind speed histograms for the meteorological station within the area (corrected for local surface roughness - see Section 2.5) to obtain the output maps of mean wind speed and mean extractable power.

2.5 Correction for local surface roughness at meteorological station

Local surface roughness has a significant effect on the wind speeds within a few hundred metres of the ground. In general, smooth level terrain will have higher measured wind speeds than rougher areas such as forest or towns. This leads to two potential inaccuracies in the present study. Firstly, the 10m data at the meteorological stations used for initialisation of the methodology will be affected by their particular local roughness values, which may also vary according to wind direction. Secondly, every other point within a modelled region will have its own associated surface roughness distribution. This second factor will have progressively less importance for wind speeds at higher levels (the friction effects decrease with height), and local roughness values for the whole UK are not currently available. A correction for this second factor has not therefore been attempted. *Instead, the aim has been to produce predictions which would be appropriate to smooth terrain, such as short grassland.*

To do this, corrections were made for the local surface roughnesses at each meteorological station used in the study, using a method recommended by the University of East Anglia Climatic Research Unit (CRU), which has investigated the vertical extrapolation of wind speeds taking account of surface roughness variations [4] based on an approach by Wieringa [5]. The starting point of the method was to assess the surface roughness and corresponding power law exponent ($1/\alpha$) for each direction sector around the initialisation station, within 5 km of each station. The wind speed data for each direction can then be corrected to provide the 10m speeds, as if the station were situated in a region of typical roughness, using the following formula:

$$V_c = V_0 \, (h_0/h_b)^{0.16} \, (h_b/h_0)^{1/\alpha} \qquad (2.2)$$

where V_c is the corrected wind speed, V_0 is the observed wind speed at height h_0, and h_b is the height of the boundary layer (taken to be 60m, following [4]). This formula effectively corrects the wind speed data to a surface roughness of $1/\alpha = 0.16$, which is appropriate for smooth, level terrain such as flat grassland.

2.6 Modelling of wind speed variation caused by change in surface roughness at the coast

The most significant effects of surface roughness on wind speed occur near the coast, and are caused by the abrupt transition between the smooth sea and the much rougher land. Thus, on average, coastal wind speeds are notably higher than those well inland. No allowance was made for the coastal change in surface roughness in deriving the UK maps of wind speed and extractable energy shown in [2].

Subsequently, the overall wind resource estimation methodology was refined to allow for this effect, using the method described in Appendix 1. This method incorporated the Engineering Science Data Unit (ESDU) internal boundary layer approach for calculating wind speed variations due to changes in surface roughness and fully took into account the measured wind rose at each of the meteorological stations used for initialisation of the overall resource estimation methodology.

2.7 Input data used for the modelling

(a) Terrain data

Digitised terrain data were obtained for the whole of the UK including Northern Ireland. The original datasets contained data sampled at approximately 100m intervals. Linear smoothing (averaging) was used to reduce this to the 1km interval needed for the present work. The final terrain dataset used for the wind resource modelling contained height values on a 1 x 1km grid, aligned with the co-ordinates of the Ordnance Survey grid. The south-west corner of the dataset was at the origin (0,0) of the Ordnance Survey grid. The dataset containing 700 points in the east/west direction and 1300 points in the north/south direction so that the dataset was bounded by the following Ordnance Survey lines:

Northing	= 0 and 1,300,000m
Easting	= 0 and 700,000m

(b) Wind data

It is well known that there can be large year to year variations in the wind resource (e.g. [6]), and it is essential that the wind data for this study covered an extended period. It was concluded that a 10 year period provided a good compromise between site availability and time period. A further constraint for a self consistent study was that data from all the stations should cover the same 10 year period. In addition, sites should not have much missing data. The period 1975-84 was chosen for this work.

The observed data from standard meteorological stations can be affected by a number of factors including:

(i) Sheltering effects due to features such as buildings, trees etc. near the anemometer site (and changes in these factors over time).

(ii) The presence of local topographical features such as cliffs.

(iii) Changes in the local position of an anemometer at a particular station.

(iv) Variations in local surface roughness in the region around the station.

For the present study, the effects of large scale topography (e.g. siting of the station on a hill top) are minimised since NOABL takes such factors into account. The importance of factors (i) to (iii) above were minimised by careful examination of site histories and by as far as possible omitting stations which are significantly affected (for further details see [2]). Local surface roughness was taken into account, as detailed in Section 2.5.

The full list of the meteorological stations used is given in [2] and Table 2.1 For each of these stations, the following data were obtained:

1. A histogram of hourly wind speeds in 30 degree direction intervals for the ten year period 1975-84.

2. Estimates of the power law exponent values ($1/\alpha$) in the same 30 degree direction intervals at the station site, to be used to correct for the effects local surface roughness (Section 2.5).

Table 2.1. Details of the regions used for NOABL modelling of the UK. The co-ordinates are given for the SW corner of each region

Region	OS Co-ords of SW corner		Size of region		Initialisation Met. station	Second Met. station
	Easting	Northing	Easting	Northing		
1	407	1123	100	100	Lerwick	
2	375	1072	100	100	Sumburgh	Lerwick
3	279	959	100	100	Kirkwall	
4	169	878	100	100	Shin	
5	249	872	100	100	Wick	Shin
6	79	869	100	100	Stornoway	
7	142	788	100	100	Duirinish	
8	232	788	100	100	Lossiemouth	Cairngorm
9	313	782	101	100	Aberdeen Dyce	Lossiemouth
10	52	781	100	101	Benbecula	
11	89	698	100	100	Tiree	
12	179	698	100	100	Rannoch	
13	219	698	100	100	Rannoch	
14	289	698	100	100	Bell Rock	
15	293	638	100	100	Bell Rock	
16	113	608	100	100	Macrihanish	
17	203	608	100	100	Prestwick	Intcherf
18	343	578	100	100	Lynemouth	
19	253	548	100	100	Eskdalemuir	
20	77	532	100	100	Macrihanish	
21	163	518	100	100	West Freugh	
22	393	502	100	100	Lynemouth	
23	10	500	100	100	Carrigans	
24	303	488	100	100	Gt Dun Fell	
25	0	470	100	100	Carrigans	
26	77	462	101	100	Aldergrove	
27	213	458	100	100	Ronaldsway	
28	419	422	100	100	Leeming	
29	393	412	100	100	Leeming	
30	303	398	100	100	Squires Gate	
31	454	378	100	100	Binbrook	
32	378	322	100	100	High Bradfield	
33	208	308	100	100	Valley	Bala
34	298	308	100	100	Shawbury	
35	508	308	100	100	Binbrook	
36	418	288	100	100	Watnall	
37	205	249	100	100	Bala	
38	556	247	100	100	Coltishall	
39	294	236	100	100	Shawbury	
40	385	232	100	100	Elmdon	
41	466	217	100	100	Cardington	
42	576	191	100	100	Honington	
43	496	164	100	100	Cardington	Heathrow
44	158	159	100	100	Brawdy	
45	255	159	100	100	Cardiff Rhoose	
46	344	148	100	100	Brize Norton	
47	416	142	100	100	Brize Norton	Heathrow
48	542	101	100	100	Dungeness	
49	465	88	100	100	Heathrow	
50	255	80	100	100	Exeter	Cardiff Rhoose
51	210	70	105	100	Exeter	
52	375	68	100	100	Boscombe Down	
53	305	58	100	100	Portland Bill	
54	195	20	100	100	Plymouth	
55	105	10	100	100	St Mawgan	Gwennap Head
56	62	1	100	100	Gwennap Head	

Table 2.2. Region scaling factors used in derivation of integrated UK maps

Region	Scaling factors 10m	25m	45m
1	1	0.999	1.003
2	1	1.001	0.997
3	0.998	1.00299	1.00798
4	0.994	0.994994	0.999964
5	1.086	1.090344	1.09686
6	1.056	1.06656	1.067616
7	0.84	0.84252	0.84336
8	1.166	1.170664	1.176494
9	1.046	1.048092	1.053322
10	0.985	0.987955	0.989925
11	0.919	0.829857	0.828019
12	0.819	0.820638	0.825552
13	0.826	0.827652	0.832608
14	1.17	1.09512	1.06236
15	1.141	1.069117	1.036028
16	0.913	0.915739	0.915739
17	1.007	1.011028	1.016063
18	0.883	0.883883	0.887415
19	0.993	0.994986	0.999951
20	0.904	0.907616	0.906712
21	1.125	1.1295	1.130625
22	0.844	0.844	0.845688
23	1.095	1.10157	1.102665
24	1.022	1.020978	1.023022
25	1.099	1.104495	1.106693
26	1.153	1.159918	1.163377
27	0.906	0.906	0.904188
28	1.049	1.049	1.052147
29	1.046	1.047046	1.049138
30	1.01	1.01101	1.00798
31	0.95	0.9557	0.9576
32	0.865	0.867595	0.86846
33	0.876	0.876	0.872496
34	1.165	1.16966	1.17199
35	0.923	0.934076	0.934999
36	1.321	1.332889	1.33421
37	0.726	0.727452	0.728178
38	1.078	1.097404	1.097404
39	1.167	1.171668	1.174002
40	1.03	1.03824	1.03927
41	1.08	1.09404	1.0962
42	1.055	1.077155	1.07821
43	1.062	1.082178	1.084302
44	1.035	1.03914	1.04121
45	1.129	1.135774	1.138032
46	1.083	1.091664	1.092747

Region	Scaling factors 10m	25m	45m
46	1.083	1.091664	1.092747
47	1.067	1.081938	1.083005
48	0.943	0.959974	0.95243
49	1.113	1.133034	1.134147
50	1.015	1.01703	1.01703
51	1.018	1.020036	1.019018
52	1.116	1.130508	1.131624
53	0.96	0.96672	0.95712
54	0.943	0.940171	0.938285
55	1.01	1.00091	1.00394
56	0.796	0.788836	0.78406
Mean	1.011089	1.01184	1.011812
SD	0.113267	0.115479	0.11572
Max	1.321	1.332889	1.33421
Min	0.726	0.727452	0.728178

3. LIMITATIONS AND PRACTICAL USAGE OF MAPS

The approach used to generate the mean UK wind speed maps necessarily included a number of approximations and limitations, as described in detail in [2]. This section presents an updated summary of these limitations and attempts to quantify the likely accuracy of the resulting maps, so that the areas of practical usage of these maps can be evaluated. It is, for example, clear that the maps are a major advance on available isovent data and are valid for overall resource studies and initial site screening.

3.1 Limitations and properties of maps

The following limitations and properties of the maps generated by this study should be borne in mind when interpreting the modelled wind speeds:

(a) The wind speeds represent 10-year means for the period 1975-84. Significant year to year fluctuations can occur in mean wind speeds, which should be borne in mind when comparisons are made with wind data collected for other periods, and also for predictions for future periods.

(b) The modelled wind speeds correspond to those that would be measured in areas in which the local surface roughness is appropriate to smooth terrain, such as short grassland. The actual wind speeds in areas of higher surface roughness would therefore be lower than those predicted.

(c) No account of thermal effects (e.g. sea breezes) was included in the methodology, but these effects are less important for the stronger winds that contribute most significantly to the wind energy resource.

(d) The modelling of the effect of terrain on wind speed was carried out at a resolution of 1 km. Thus the modelled wind speeds are expected to be most reliable in areas in which the terrain is smoothly varying on this length scale, and less reliable in areas of rapidly varying complex terrain (e.g. cliffs, abrupt escarpments etc.).

(e) Measurements indicate that the wind speeds at different positions within an individual 1km square area can vary by $\pm$1m/s or more depending on the complexity of the local terrain. The wind speeds predicted by the methodology should approximate to the mean wind speed in each 1km square area, with the proviso that the predictions are apparently slightly conservative estimates of wind speed in areas of hilly/mountainous terrain (see Section 3.3, below).

(f) The available information on the accuracy/consistency of the wind speeds predicted by the methodology is summarised below.

3.2 Internal consistency of meteorological station data

3.2.1 Results from regions containing two meteorological stations

Eight of the 56 regions within the UK contained two meteorological stations. For these regions, one of the stations was used for initialisation and so the modelled wind speeds for that station agreed precisely with the measured values (before application of the scaling factors used to incorporate the results from the individual regions into the complete UK maps). However, the measured wind speeds for the second stations can usefully be compared with the predicted values, which are fully independent of the second station results before application of the region scaling factors.

A comparison of the measured and predicted mean wind speeds for these eight regions containing two meteorological stations showed that, on average, the measured and predicted speeds agreed very well, with a mean difference of only 0.1 m/s. The individual differences were also low, with a standard deviation of 0.65 m/s. The largest difference obtained was -1.33 m/s, but this occurred for the Gwennap Head station in region 55, which is known to be somewhat unreliable due to proximity to a cliff. For the more reliable stations, the largest difference was then only 0.74 m/s.

Thus the methodology led to generally accurate predictions for wind speeds at the eight meteorological stations for which another station is available for initialisation within the same region, i.e. less than 100 km distant.

3.2.2 Differences in average wind speed between neighbouring regions

The areas of overlap in the UK regions (Fig. 2.1) enabled the predicted wind speeds from the different regions to be combined so as to obtain smooth variation over the UK as a whole. This was achieved by applying a different linear scaling factor to all the wind speeds in each region, as given in Table 2.2

The departures of these scaling factors from unity gave a measure of the degree of internal consistency achieved by the modelling methodology over the UK as a whole. The mean value of this distribution is 1.010, since on average the matching technique did not change significantly the overall mean wind speeds of all the regions. The standard deviation of the scaling factors was 0.12, which indicated that roughly 68 percent of the regions required scaling by $\pm$12 percent, or less. For the UK 25 m average wind speed of 6.2 m/s, this standard deviation corresponds to $\pm$0.7 m/s.

This figure of $\pm$12 percent ($\pm$0.7 m/s at a height of 25m) may also be interpreted as a measure of the degree of consistency between the wind speeds measured by neighbouring meteorological stations within the network of stations selected for this study. Typically these stations were separated by about 100km and were generally situated in areas of relatively flat terrain.

The meteorological stations used in this study were selected to have a minimum of any local features that might affect the wind speed data in ways that could not be taken into account by the modelling methodology (e.g. cliffs, buildings, dense forests etc.). Thus in areas of similar terrain, the wind speeds predicted by the overall methodology are likely to be accurate to around $\pm$0.7m/s at a height of 25m.

3.3 Limitations of NOABL model

The effect of hilly or mountainous terrain on wind speeds was predicted using the NOABL computer model, which introduces uncertainties additional to those described above for areas of flat terrain.

Burch et al. [2] compared the NOABL predictions for a number of hill sites with observed data. The regions involved were modelled for the various specific time periods of the data available. The results indicated that in general the NOABL modelling methodology gave a slightly conservative average estimate for the effects of terrain on wind speed, with the mean predicted value being only 0.56 m/s less than the measured value. The individual differences obtained at the various hill sites were however larger, and the standard deviation of the differences amounted to 1.54 m/s. The poorest agreement was obtained for the summit of the Cairngorm mountain, where the predicted speeds were 2 and 3.5 m/s *less* than those observed in two different time periods. This discrepancy was attributed to the smoothing of the terrain data to 1km resolution. For other hill sites, with less rapidly varying terrain, the agreement between measured and predicted wind speeds was significantly better (the predicted speeds were between 1.8 m/s stronger and 0.8 m/s weaker than those measured).

4. UK WIND SPEED MAPS

4.1 Plots of 25m wind speed maps

The predicted UK wind speed map for 25m height is shown in Fig. 4.1, incorporating modelling of the effects of both terrain and coastal surface roughness changes. Colour coding is used to show the different wind speeds. Each colour represents a 0.5 m/s interval of wind speeds. The lowest wind speed shown is 4 m/s and the highest is 12 m/s. An Ordnance Survey (easting, northing in km units) grid has also been superimposed on the map, for reference purposes. Because of the limited resolution of the display device available, the resolution of this plot is only 2 x 2 km, compared with the actual 1km resolution of the map itself.

To illustrate the actual 1 x 1 km resolution of the digital maps themselves, plots of a network of 18 regions of size 200x200 km covering the whole UK are also given. An index to these regions is given in Figure 4.2. On these plots, the individual 1km pixels can be discerned, and the colour coding shows the predicted 25m wind speed to a precision of 0.5m/s.

4.2 Statistics derived from wind speed maps

Table 4.1 gives statistics derived from the three mean wind speed maps at 10m, 25m and 45m above ground level. As expected, the variation with height in the mean wind speeds averaged over the whole UK reflects the power law expression given in equation 2.1, with an exponent of 1/7, as used in the NOABL modelling. Thus the mean wind speed averaged over the whole UK rises from 5.5 m/s at 10m to 6.2 m/s at 25m and 6.8 m/s at 45m.

Table 4.1 Wind speed statistics (10 year means in m/s) derived for whole UK

	Height above ground level (m)		
	10	25	45
Minimum speed	0.3	0.8	1.4
Maximum speed	16.5	16.3	15.8
Mean speed	5.45	6.22	6.8
Standard deviation	1.2	1.15	1.12

It can also be seen that, as expected, the effects of the terrain on the modelled wind speeds decrease somewhat with height above ground, with the minimum and maximum speeds at 10m being 0.3 and 16.5 m/s, compared with values of 1.4 and 15.8 m/s at 45 m. The standard deviation of the variation in mean wind speeds across the UK is 1.2 m/s for 10m and 25m, and 1.1 for 45m. For 45m this standard deviation represents a smaller fractional variation than at 10m since the mean values increase with height.

The variation in the modelled wind speeds is substantially greater than that given in standard isovent maps, which show mean wind speeds between 4.5 and 7 m/s.

5. CONCLUSIONS

The wind speed software package for an IBM-PC or true compatible provides the user with access to predicted UK maps of mean wind speed at heights of 10m, 25m and 45m above ground level on a 1 x 1km grid. These maps were generated as part of a comprehensive programme, funded by the UK Department of Energy, to apply computer modelling methods to the estimation of the UK wind energy resource.

Comparison of the predicted annual mean wind speeds with observed values for a number of hill top sites showed good overall agreement, and it was concluded that the effects of terrain smoothing will provide slightly conservative estimates of the wind resource.

Information about the internal consistency of the results was obtained by comparing the modelled mean wind speeds in the areas of overlap between different 100 x 100 km regions, prior to the generation of the integrated UK maps. To generate a single UK map in which the 'joins' between the individual regions were hardly apparent, it was necessary to scale the wind speeds in the individual regions by factors which ranged from 0.73 to 1.33 (standard deviation 0.12). Thus, roughly 68 percent of the regions required scaling by ± 12 percent (corresponding to ± 0.7 m/s for the 25m winds), or less.

The meteorological station network was selected so that 8 regions contained a second station, in addition to the initialisation station. This enabled a further validation to be undertaken by comparing the predicted with observed mean wind speed values at the second stations. On average, the observed and predicted speeds agreed very well, with a mean difference of only 0.1 m/s and a standard deviation of 0.7 m/s.

Standard isovent maps (based mainly on stations in flat terrain) show long term annual mean wind speeds at 10m height varying between about 4.5 and 7 m/s over the whole UK with only a few coastal regions over 6 m/s. The present study shows 10m mean wind speeds varying from 0.3 to 16.5 m/s with 23% of the UK land area having mean speeds above 6 m/s.

ACKNOWLEDGEMENTS

This programme was funded by the Department of Energy. The wind data, together with information about meteorological station site histories and advice on the station network was provided through the Climatic Research Unit of the University of East Anglia. Dr Colin Wood, University of Oxford provided consultancy on the method used to model the effect of the coastal change in surface roughness on wind speeds. Particular thanks are due to Dr. H.G. Parkinson (ETSU) for valuable comments on this work.

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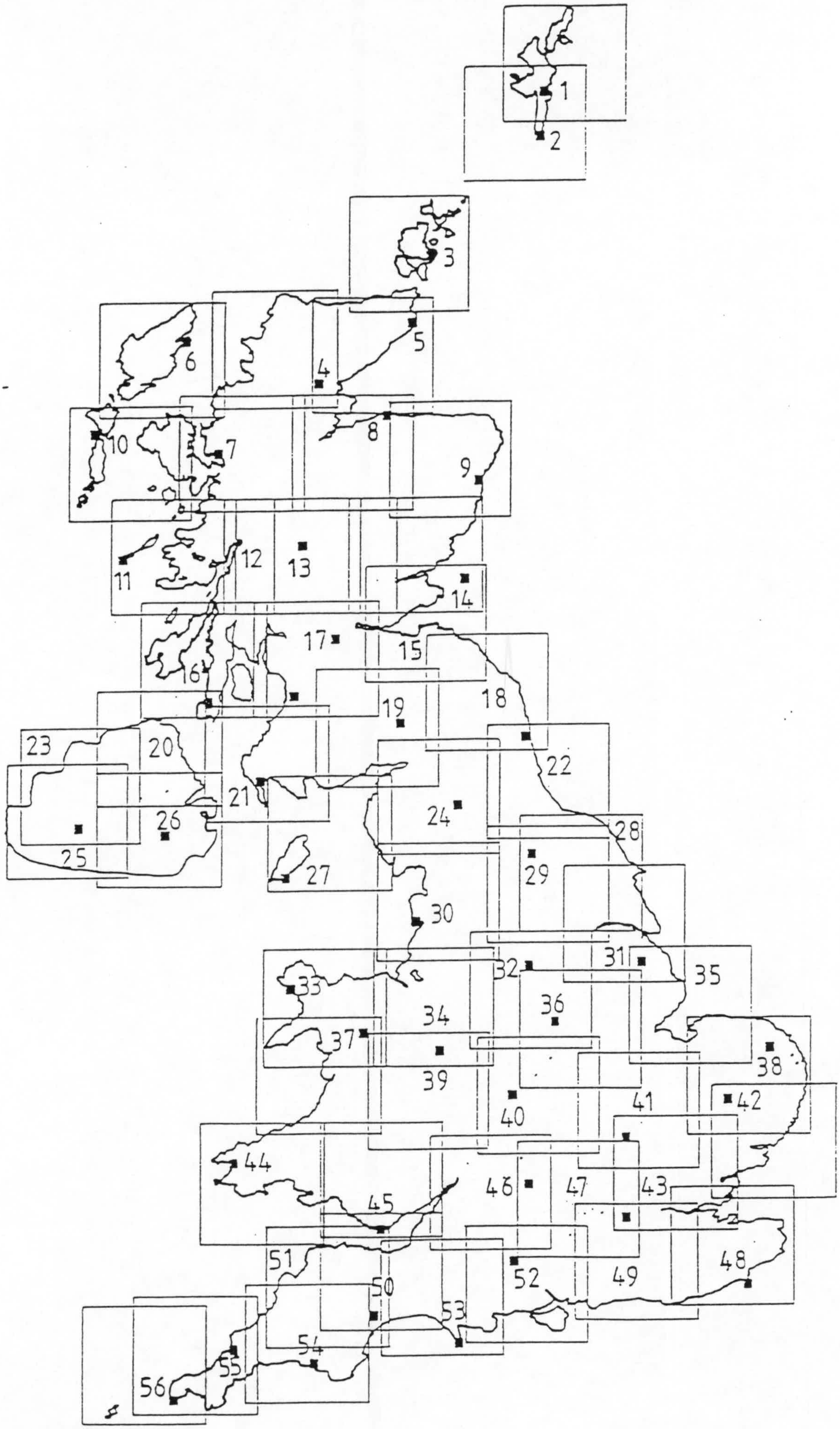


Figure 2.1 The network of meteorological stations together with the layout of the 100 x 100 km regions used for application of the resource methodology

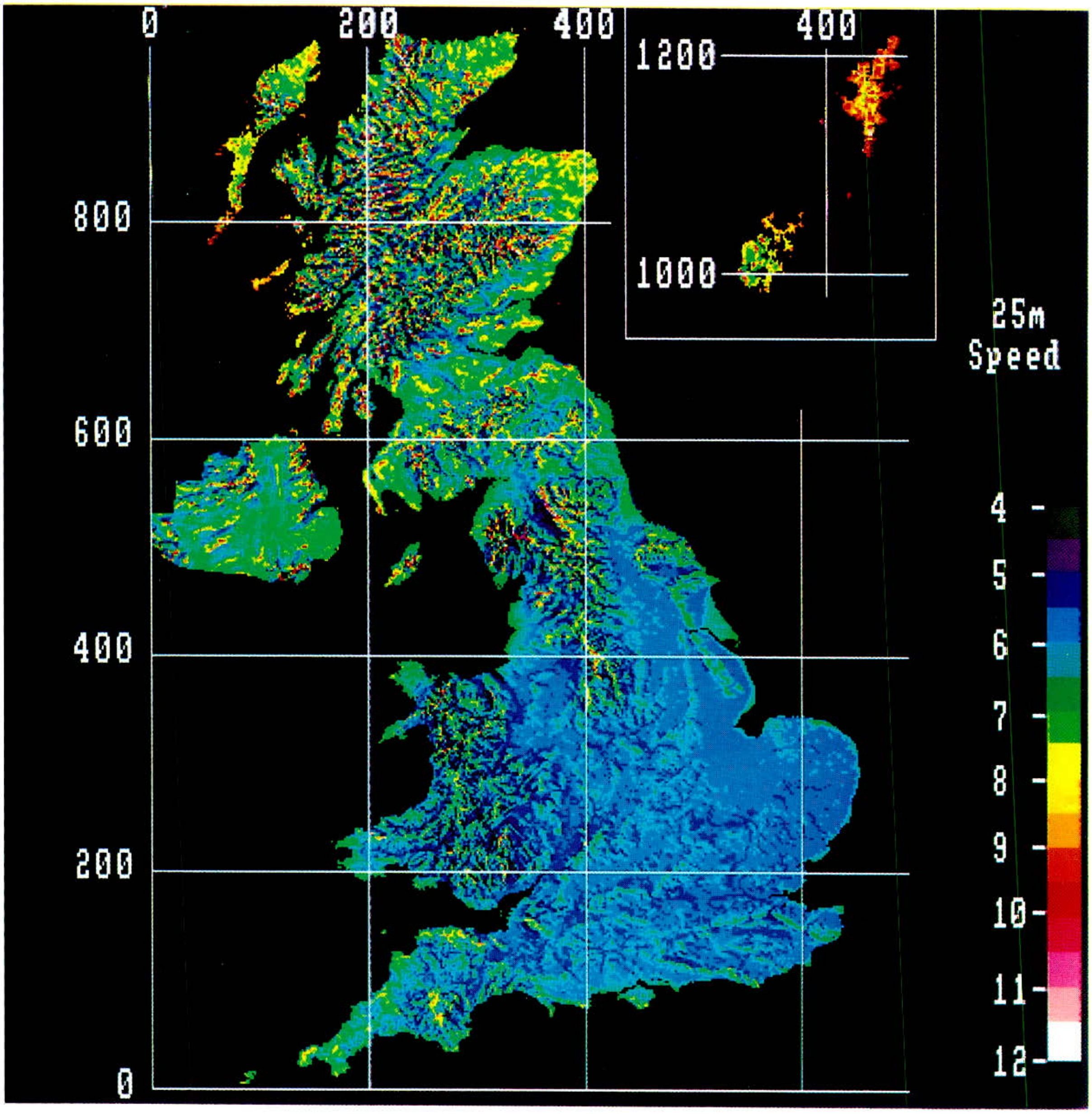


Figure 4.1 Whole UK map showing effect of terrain and change in coastal surface roughness on 10-year mean wind speed at a height of 25m above ground level. The grid shows Ordnance Survey easting and northing co-ordinates in km.

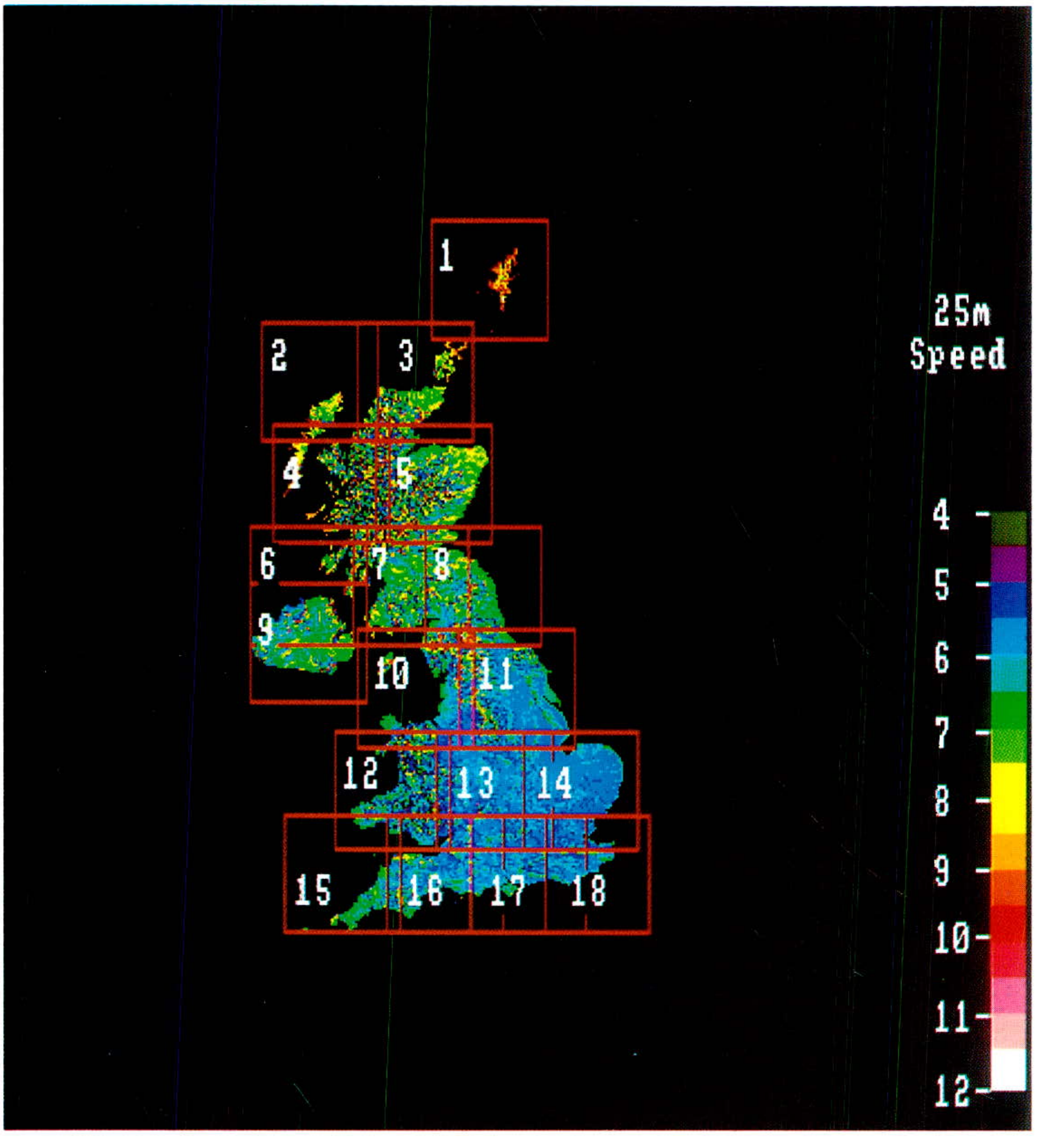
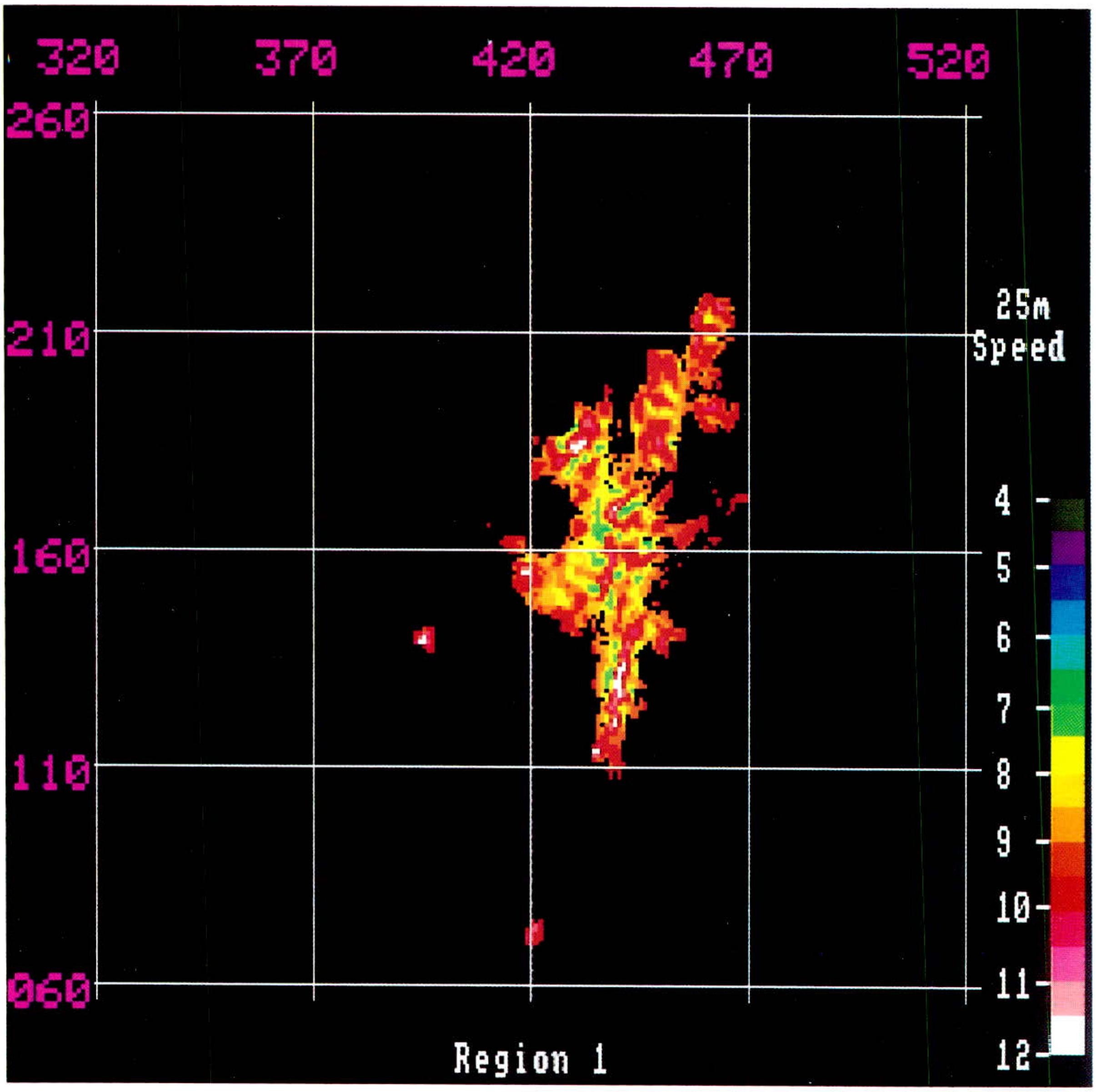
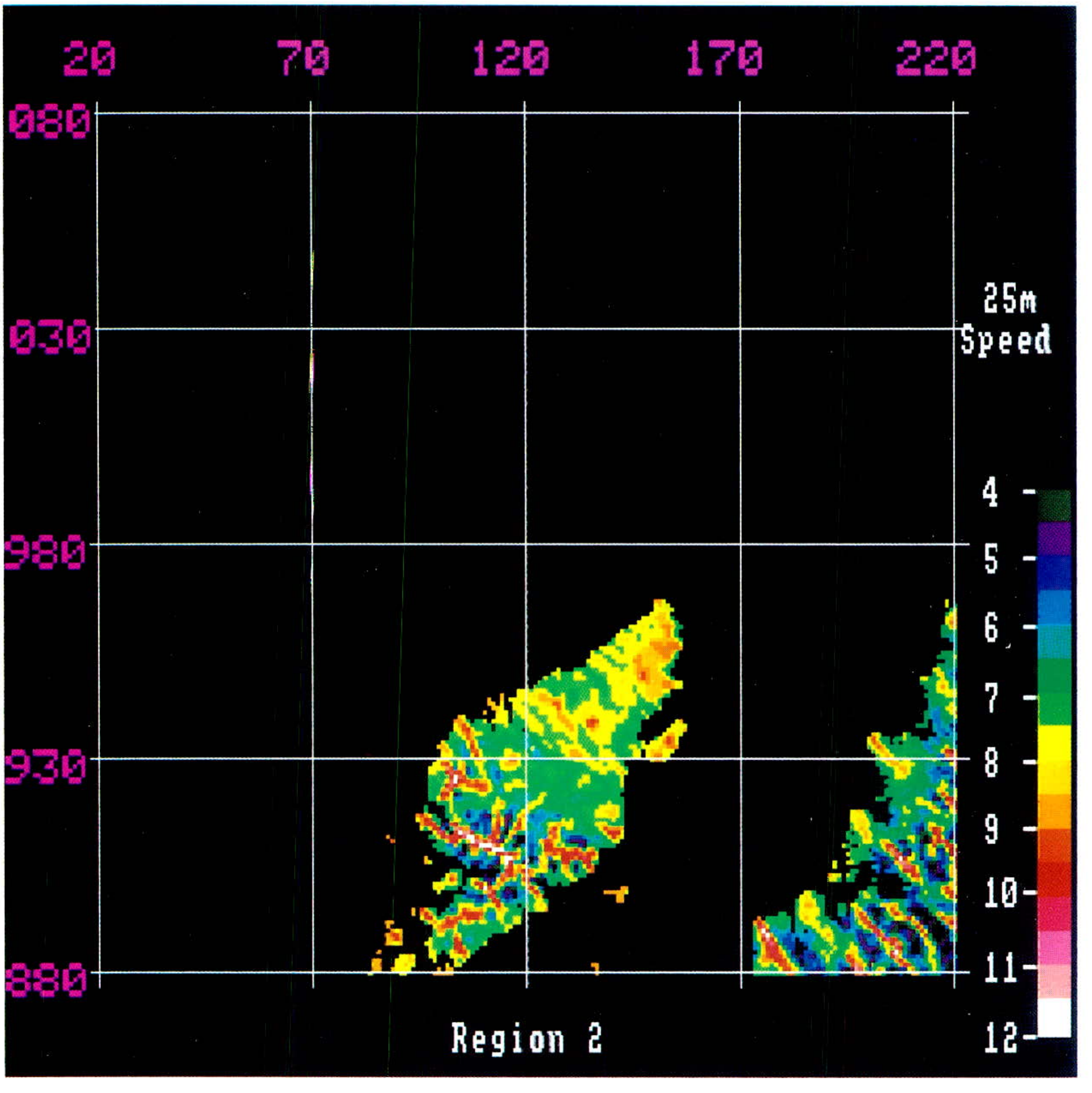
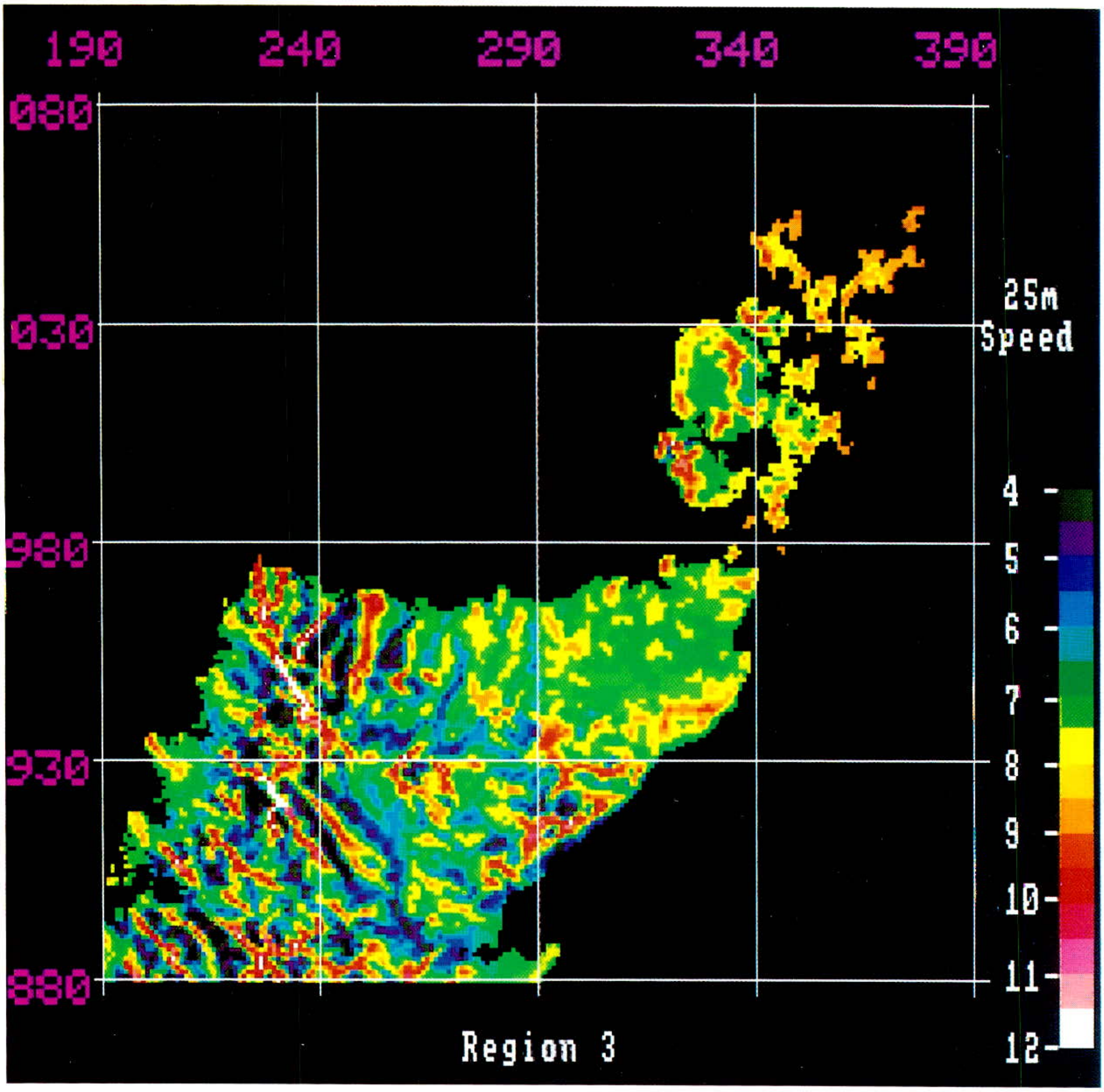


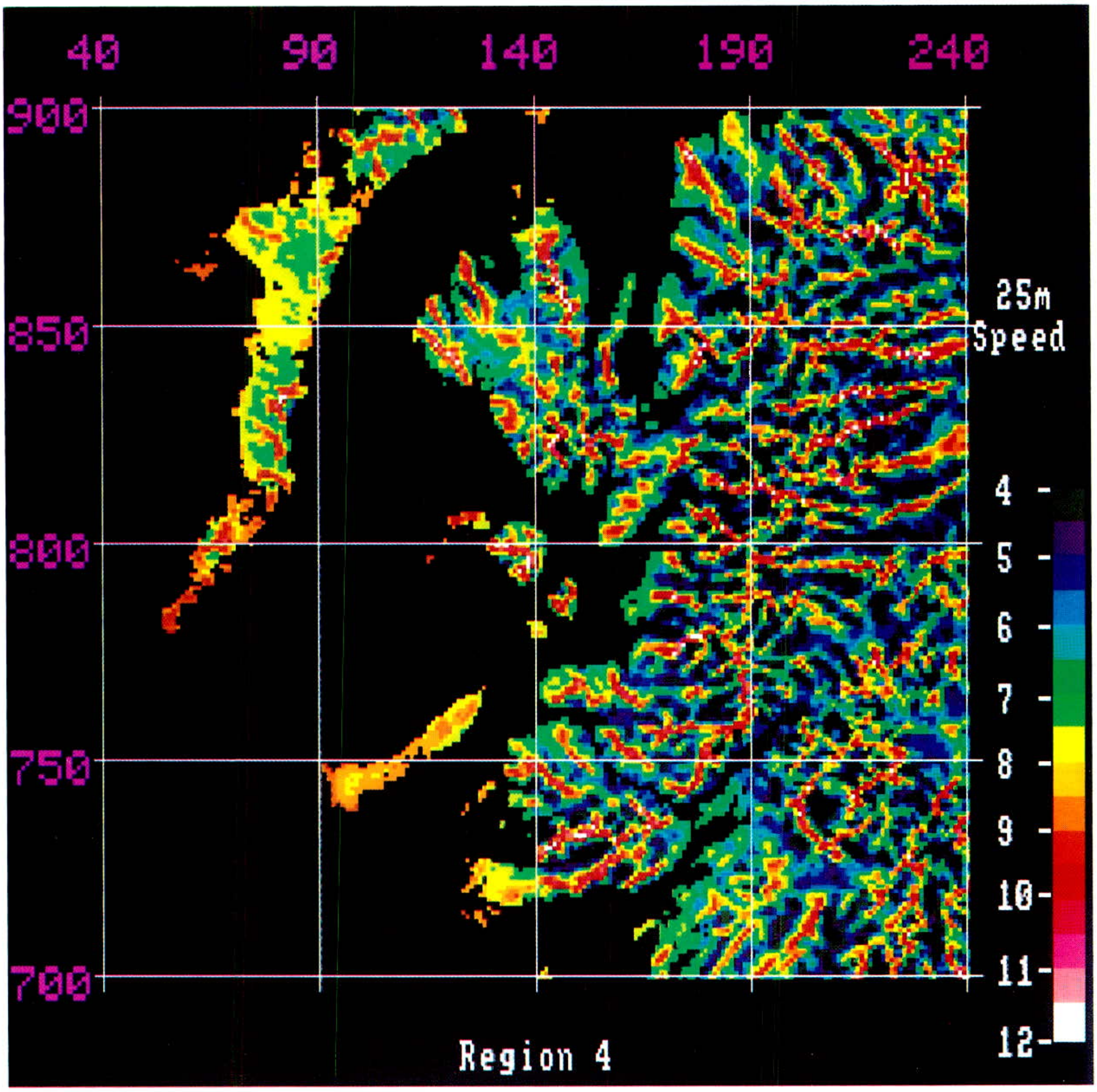
Figure 4.2 Whole UK map of predicted 25m wind speeds, providing an index to the 18 regions of size 200 x 200km which are shown on the following plots.


320
370
420
470
520
260
210
160
110
060
25m
Speed
4
5
6
7
8
9
10
11
12
Region 1

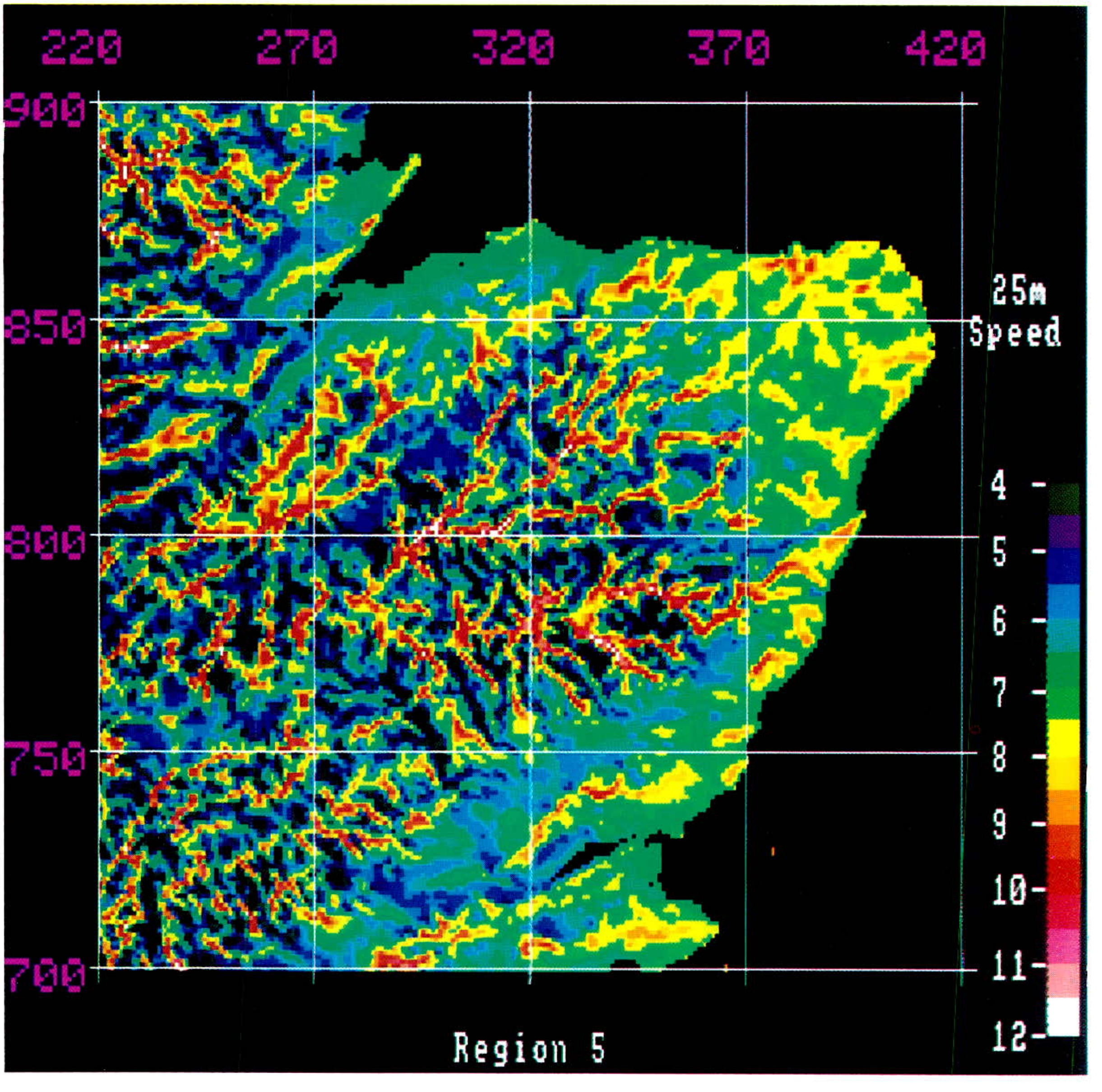

20
70
120
170
220
080
030
980
930
880
25m
Speed
4
5
6
7
8
9
10
11
12
Region 2

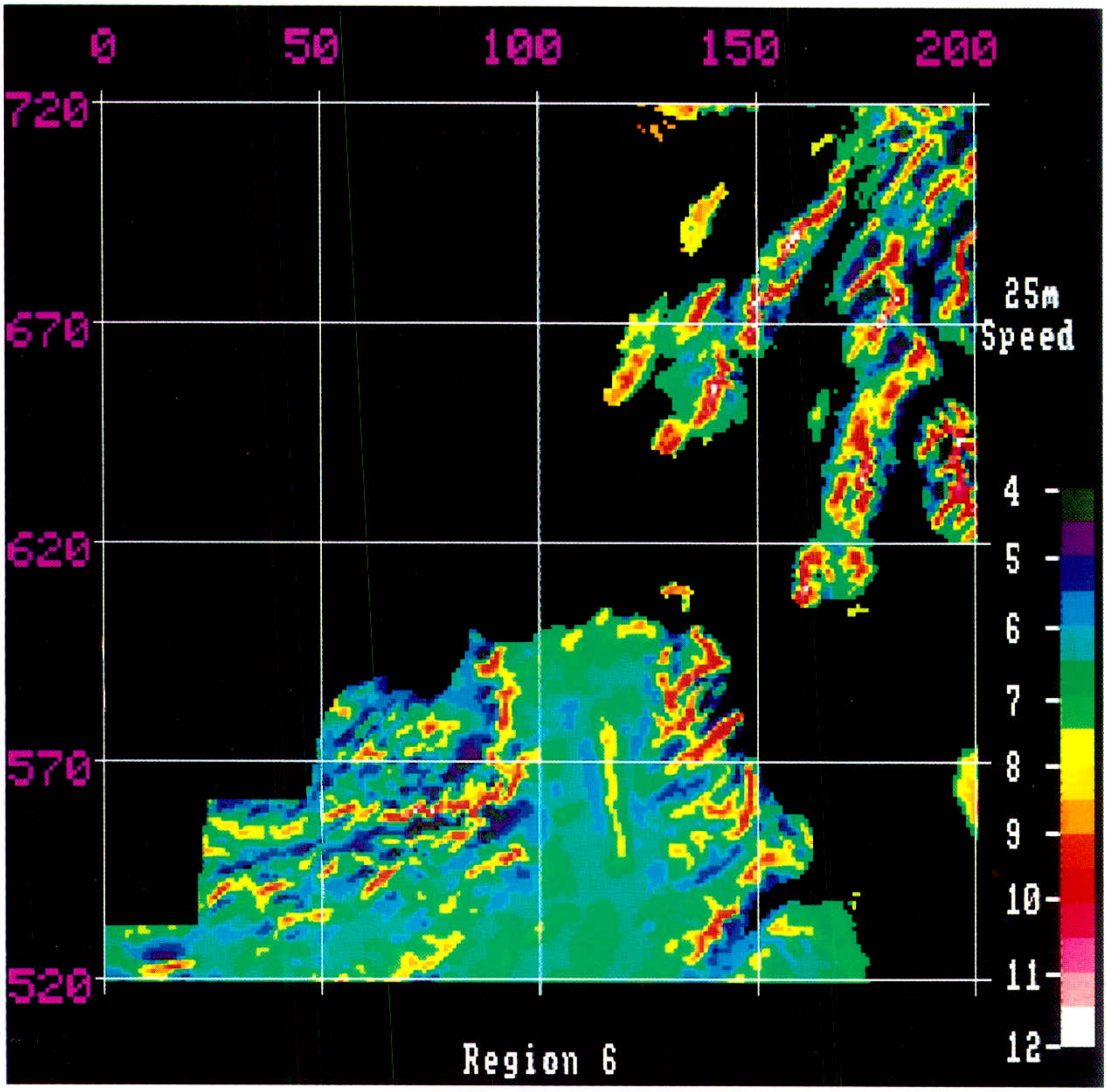


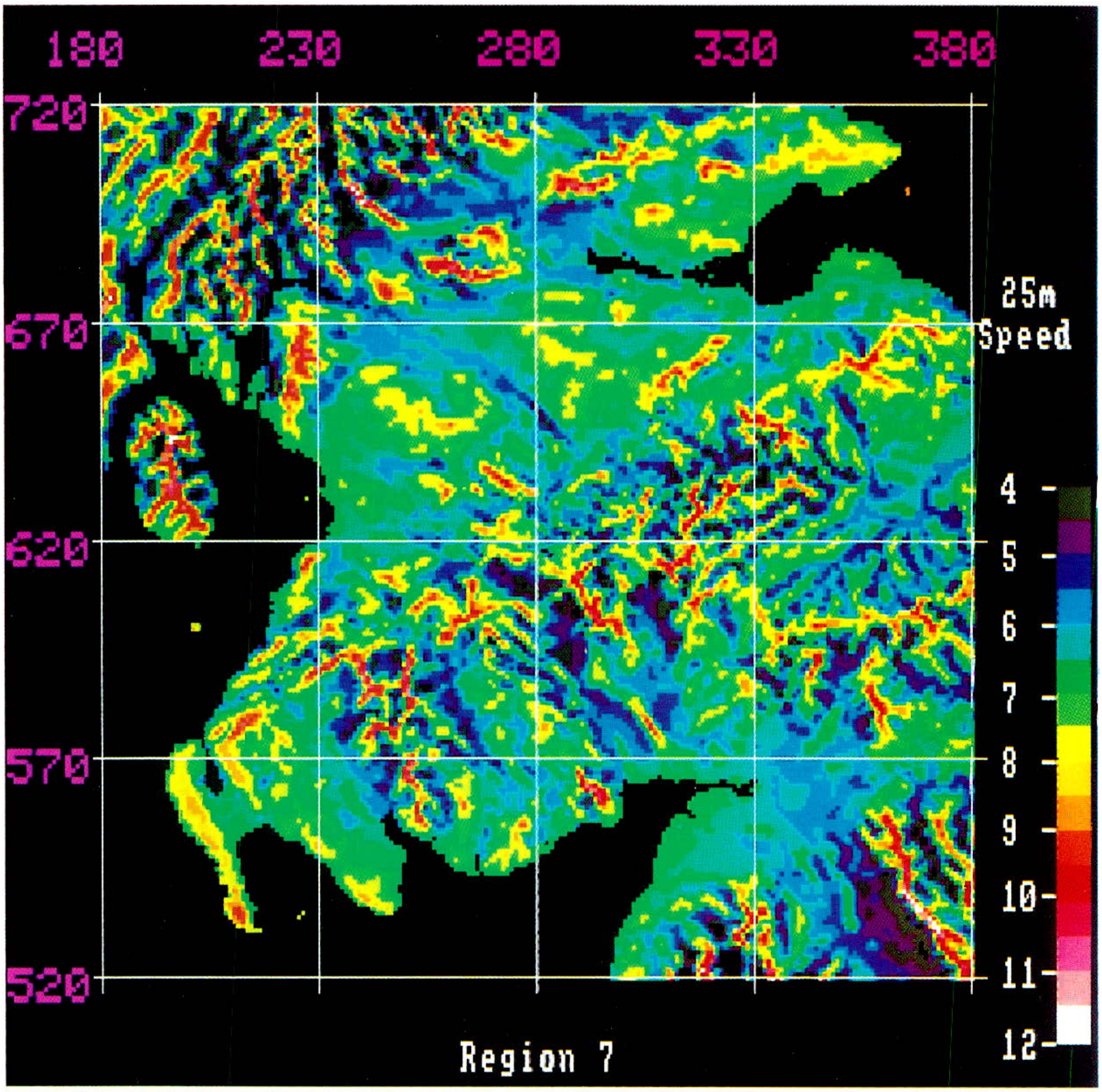
190
240
290
340
390
080
030
980
930
880
25m
Speed
4
5
6
7
8
9
10
11
12
Region 3

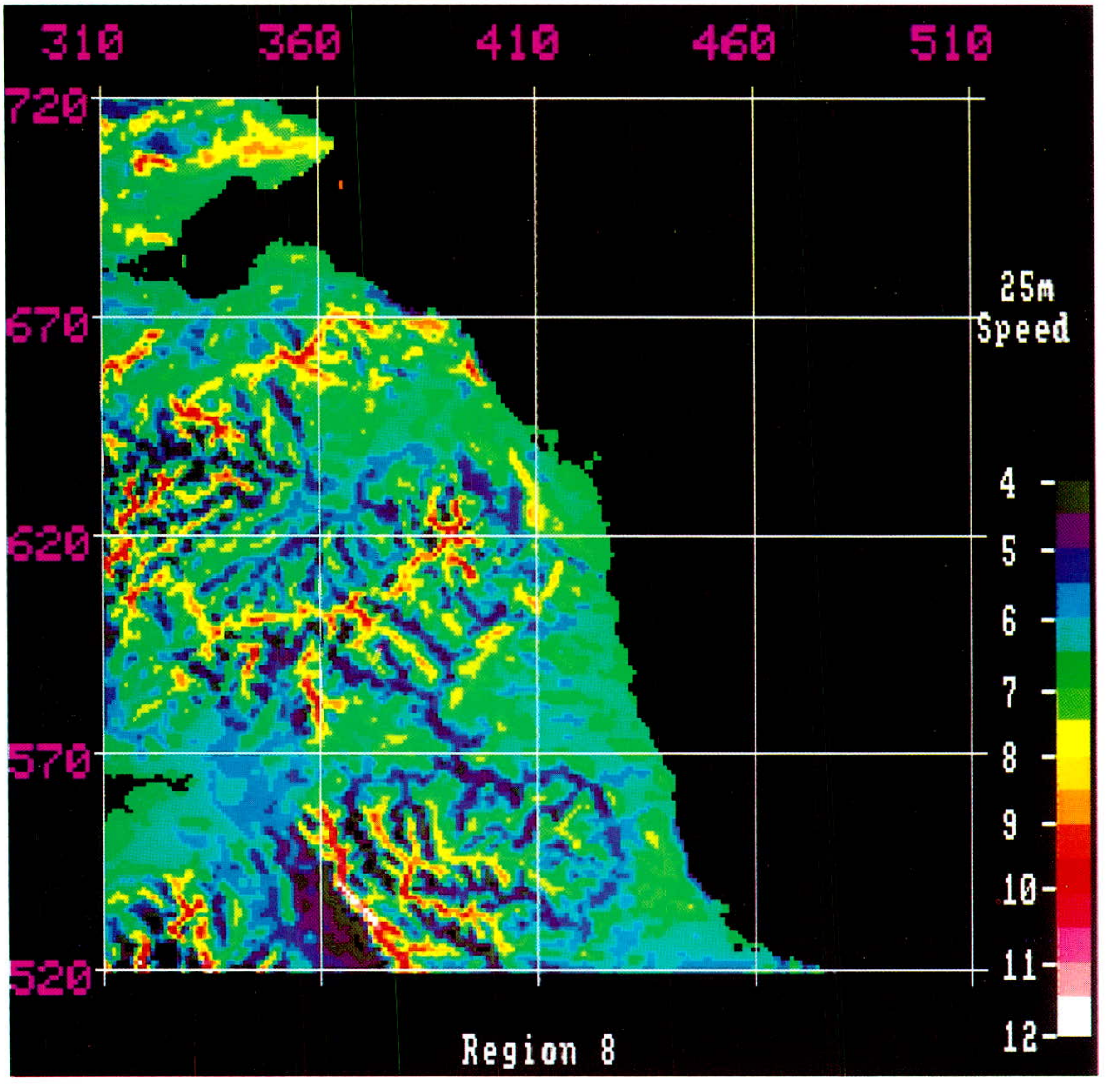


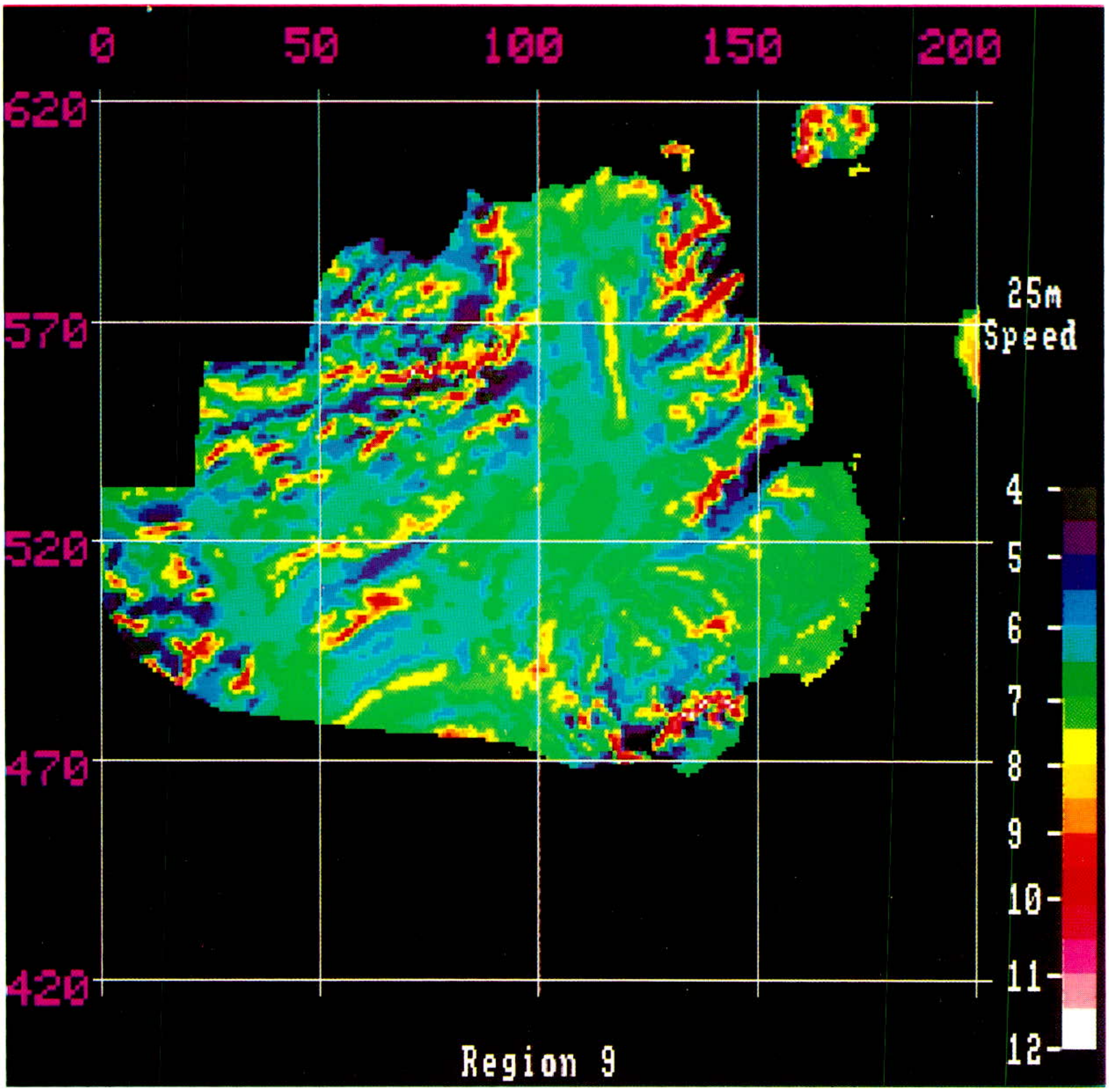
40
90
140
190
240
900
850
800
750
700
25m
Speed
4
5
6
7
8
9
10
11
12
Region 4


220
270
320
370
420
900
850
800
750
700
25m
Speed
4
5
6
7
8
9
10
11
12
Region 5

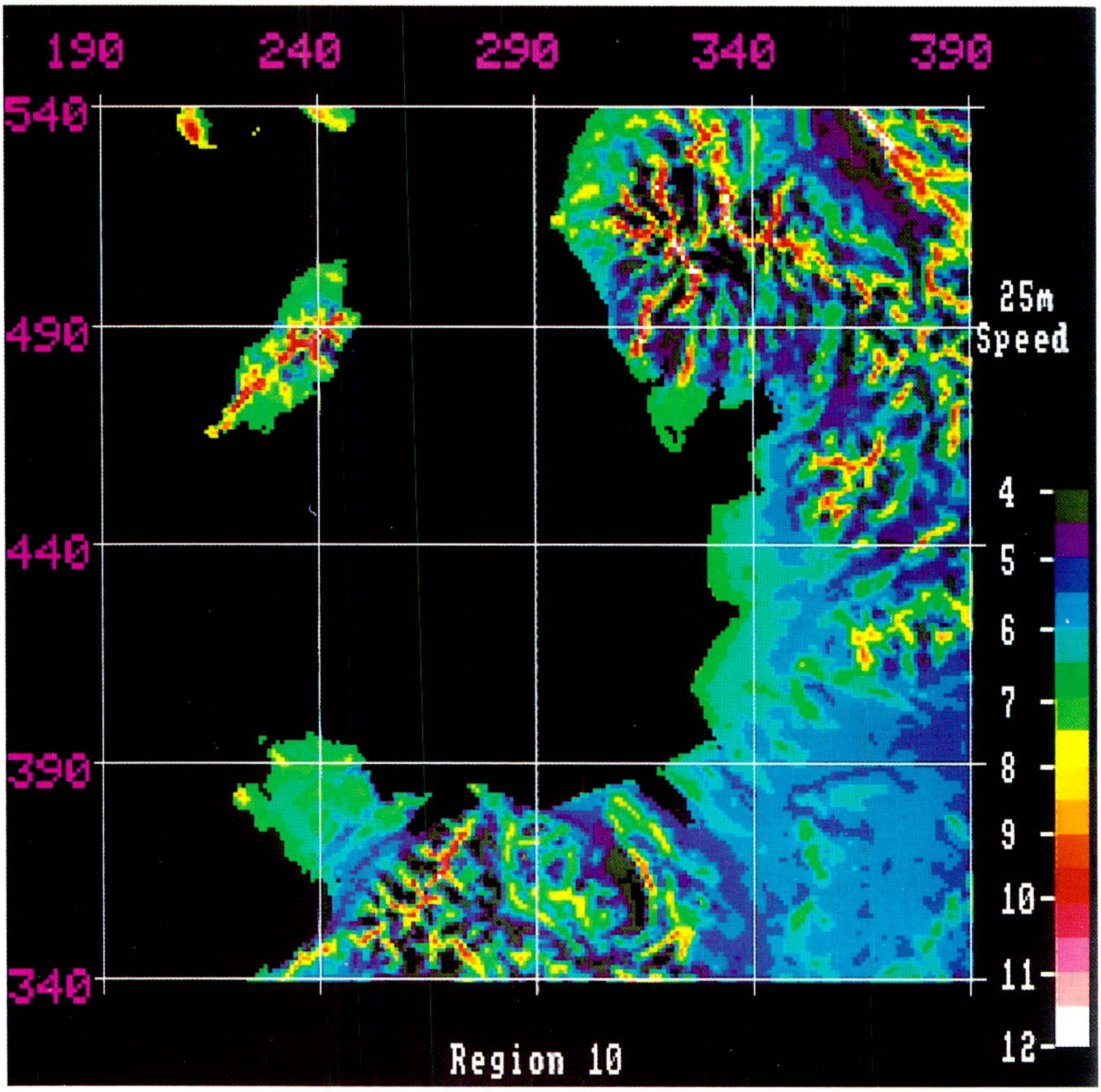

0
50
100
150
200
720
670
620
570
520
25m
Speed
4
5
6
7
8
9
10
11
12
Region 6


180
230
280
330
380
720
670
620
570
520
25m
Speed
4
5
6
7
8
9
10
11
12
Region 7

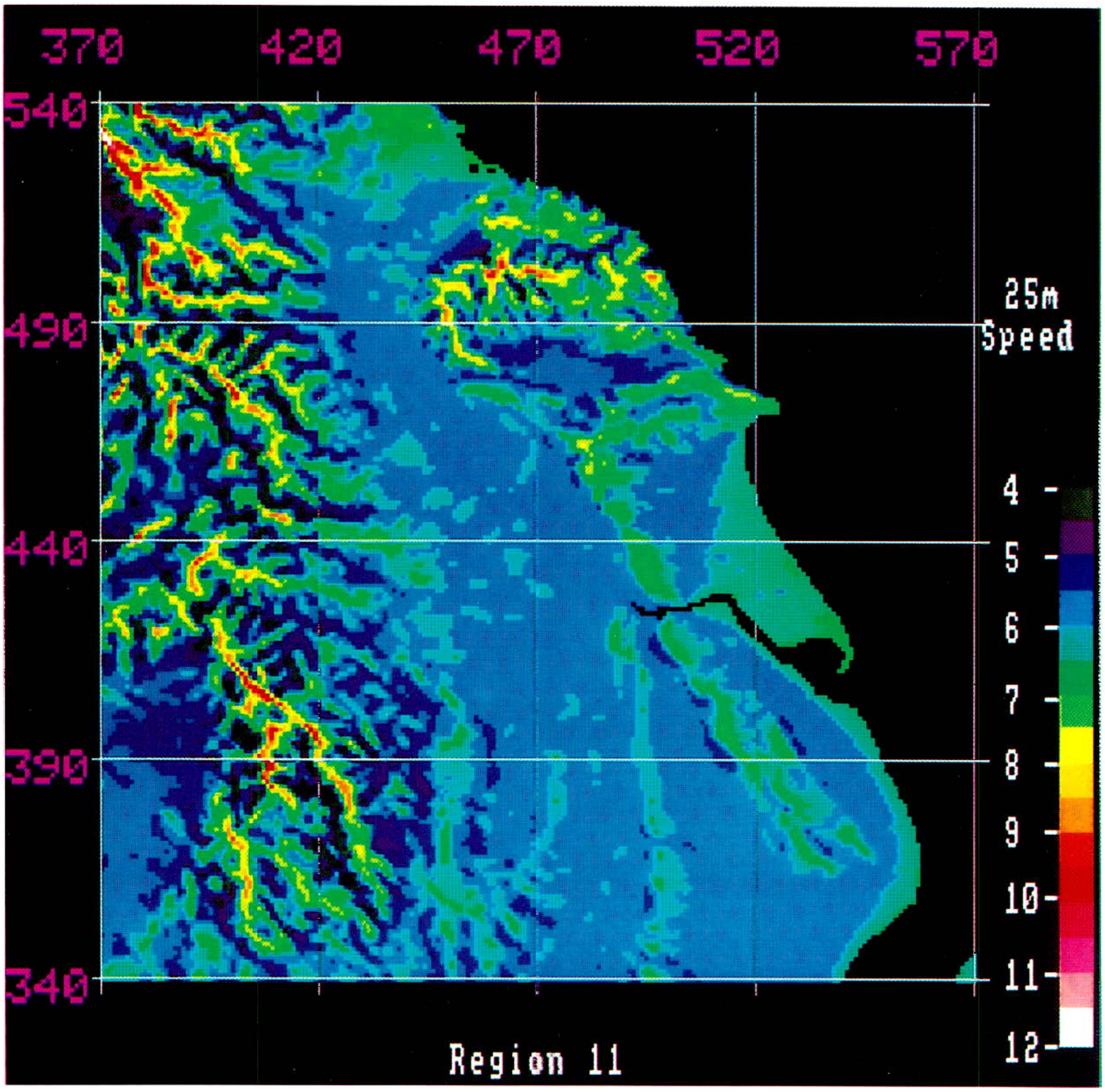

310
360
410
460
510
720
670
620
570
520
25m
Speed
4
5
6
7
8
9
10
11
12
Region 8



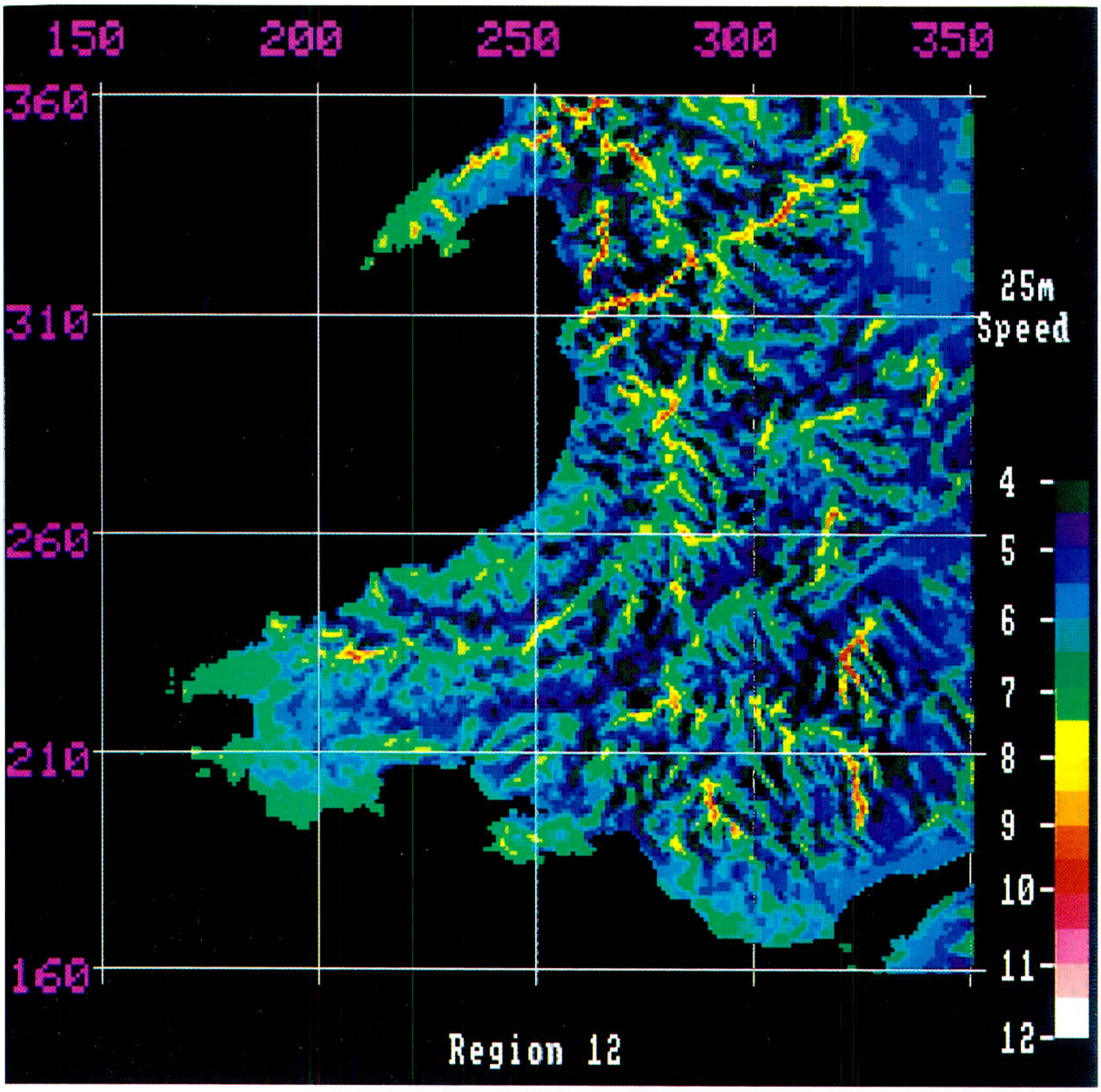
0
50
100
150
200
620
570
520
470
420
25m
Speed
4
5
6
7
8
9
10
11
12
Region 9

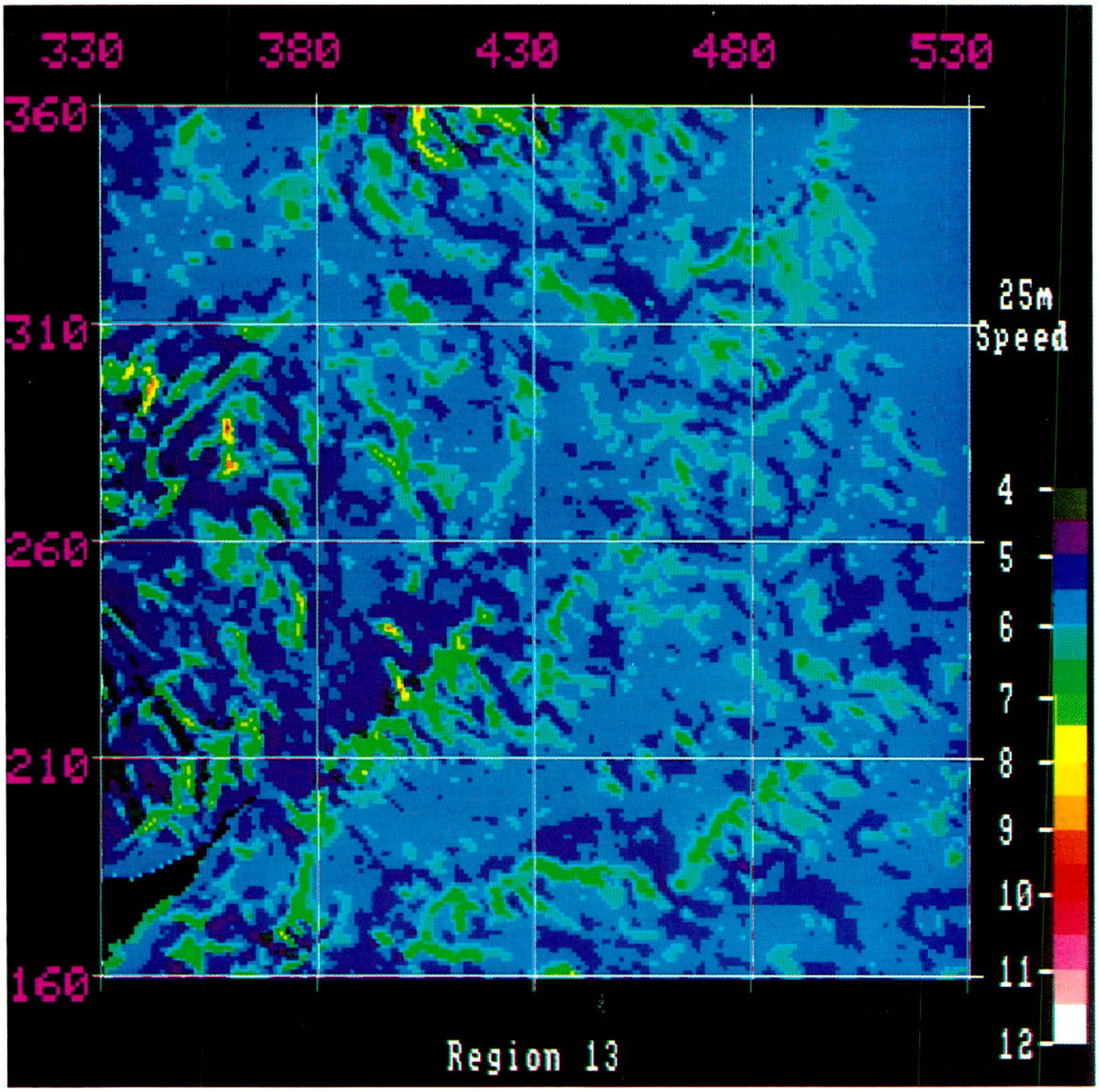


190
240
290
340
390
540
490
440
390
340
25m
Speed
4
5
6
7
8
9
10
11
12
Region 10

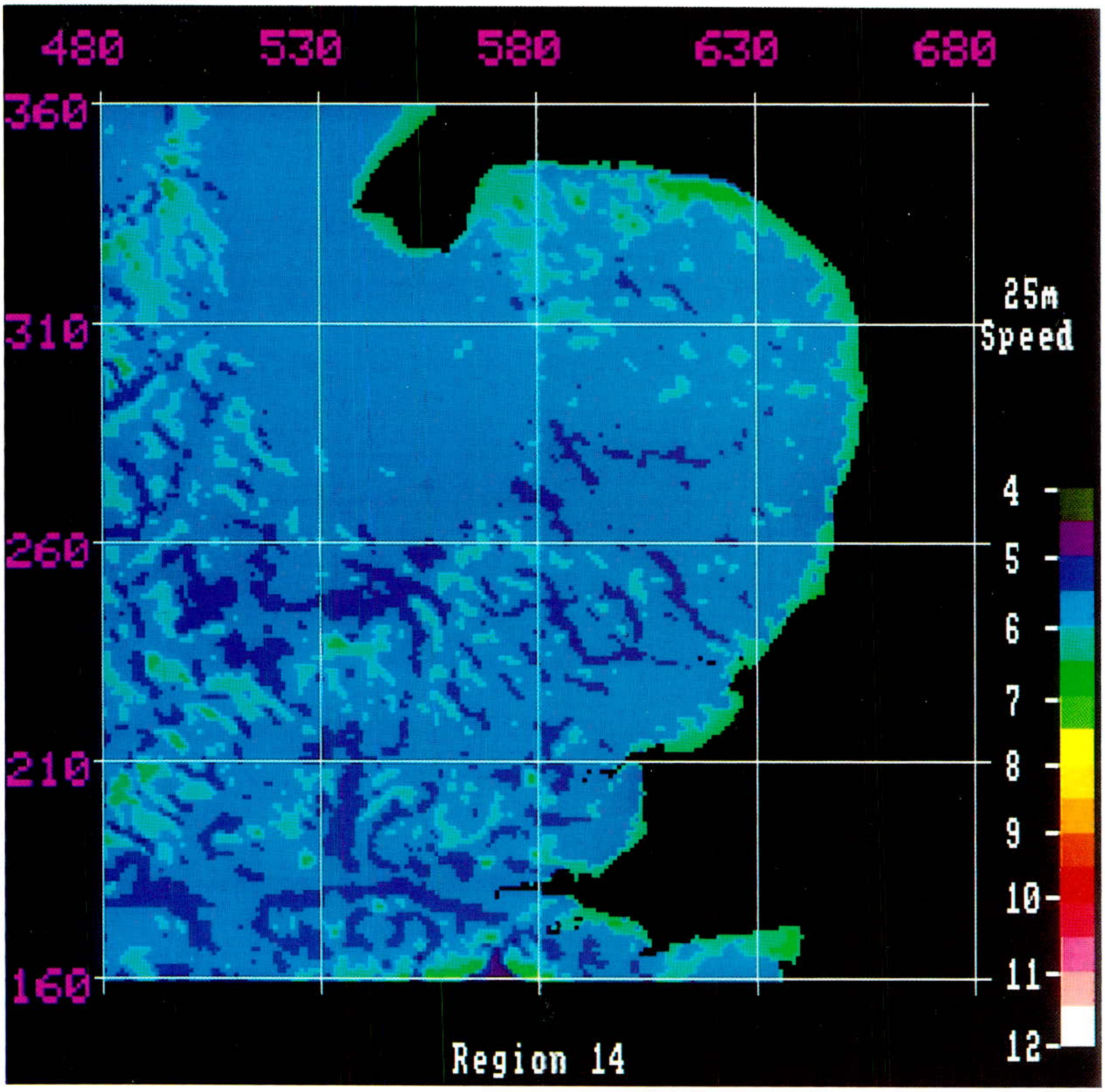


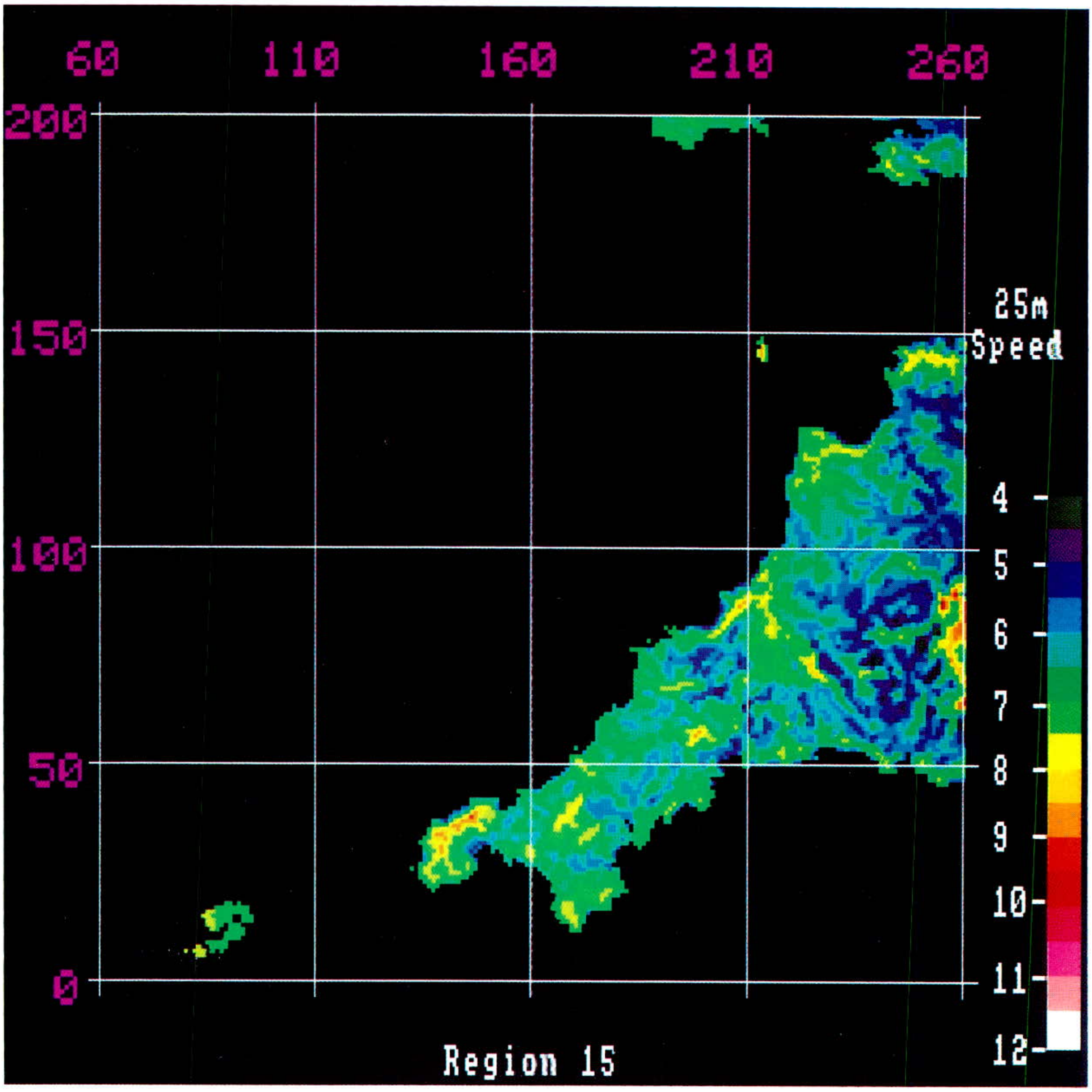
370
420
470
520
570
540
490
440
390
340
25m
Speed
4
5
6
7
8
9
10
11
12
Region 11

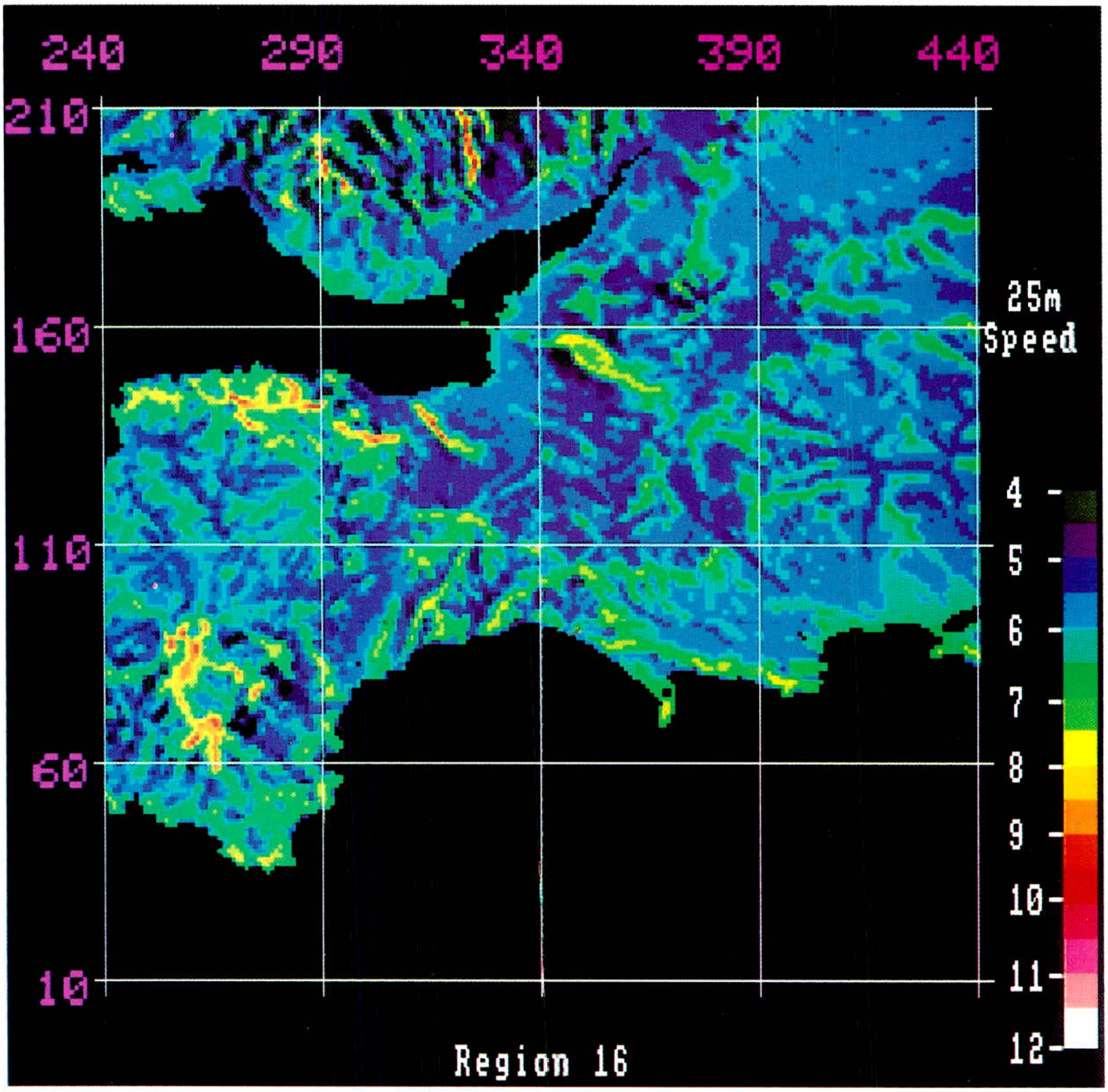

150
200
250
300
350
360
310
260
210
160
25m
Speed
4
5
6
7
8
9
10
11
12
Region 12



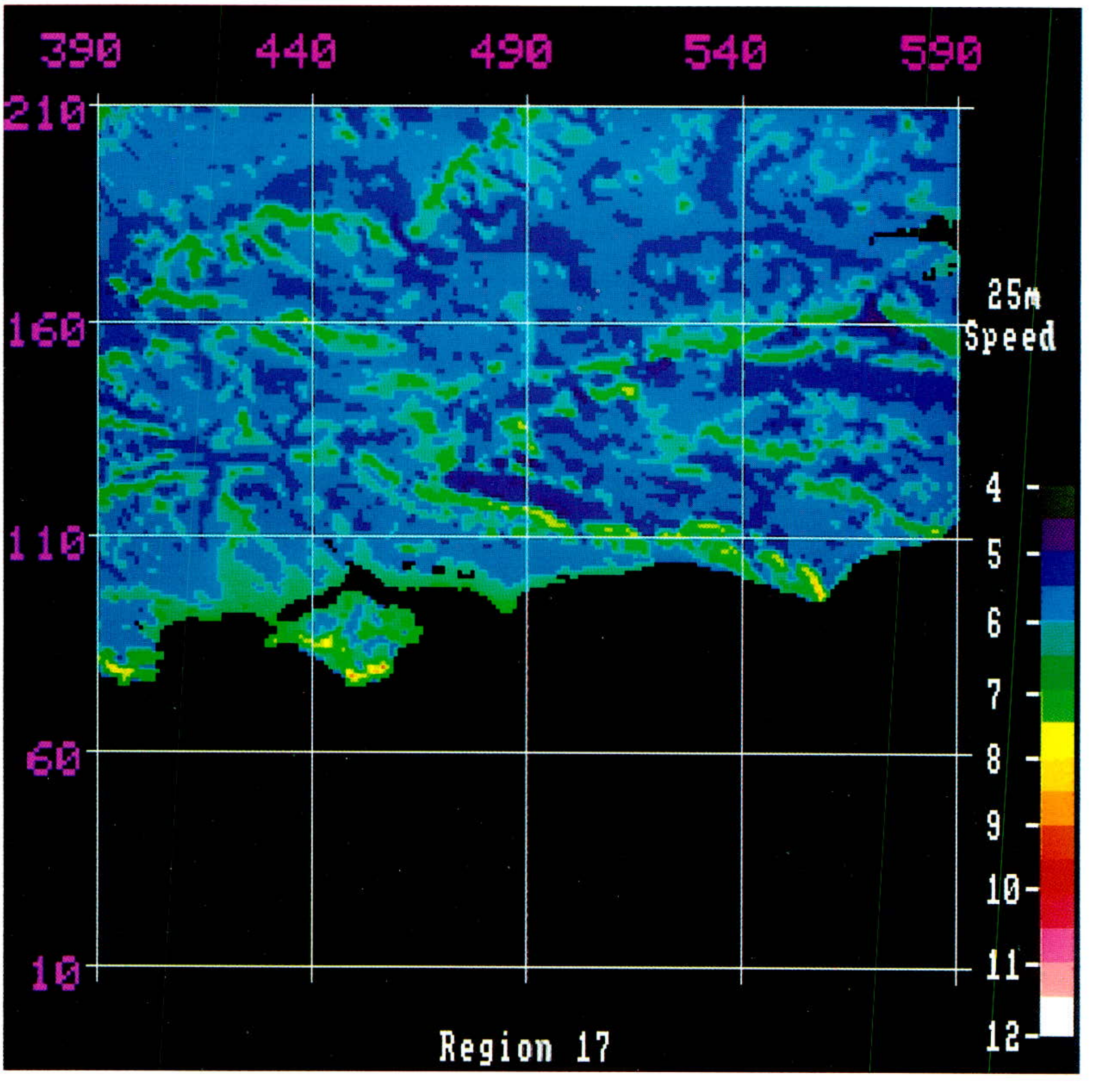
330
380
430
480
530
360
310
260
210
160
25m
Speed
4
5
6
7
8
9
10
11
12
Region 13

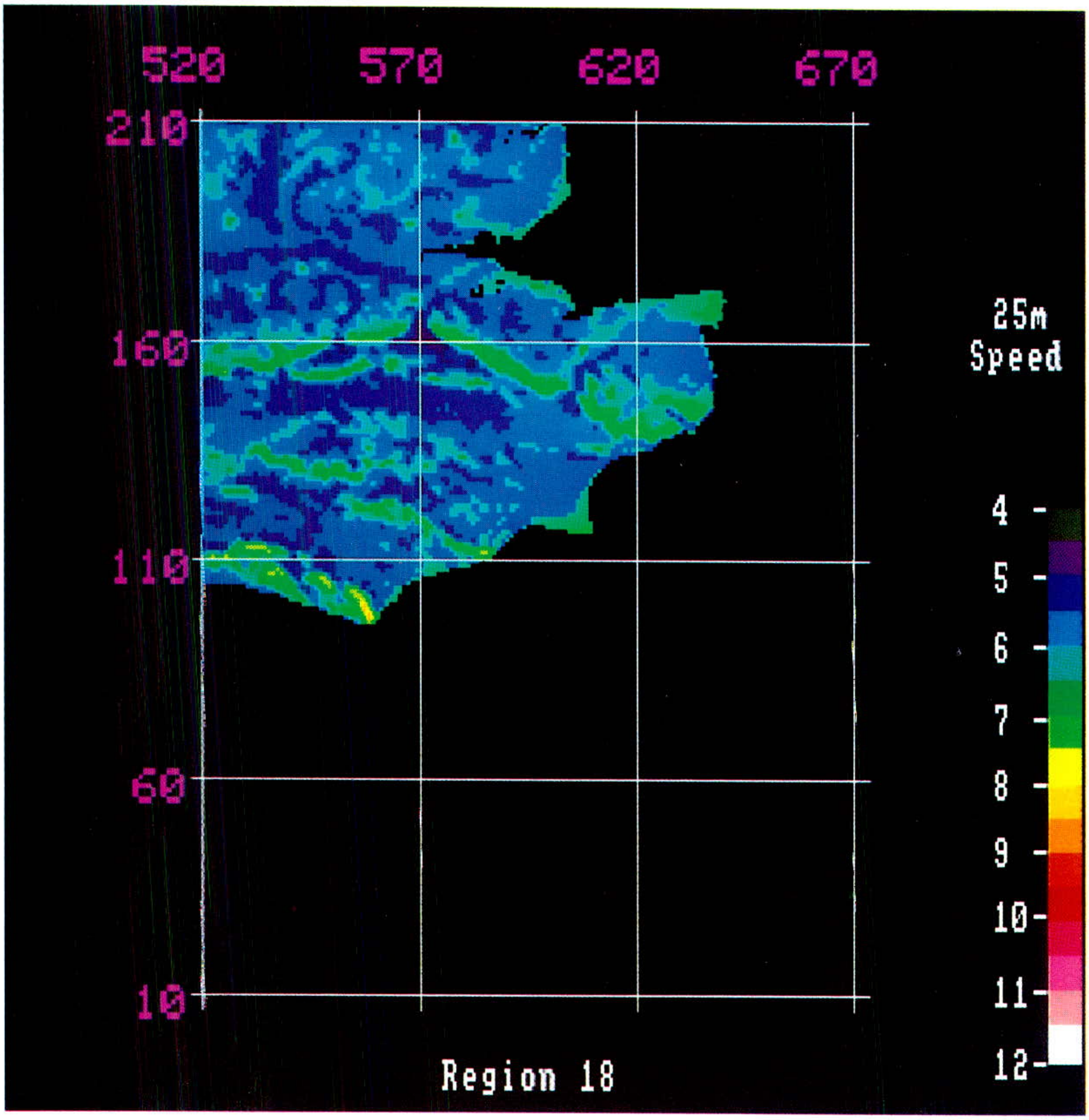

480
530
580
630
680
360
310
260
210
160
25m
Speed
4
5
6
7
8
9
10
11
12
Region 14


60
110
160
210
260
200
150
100
50
0
25m
Speed
4
5
6
7
8
9
10
11
12
Region 15



240
290
340
390
440
210
160
110
60
10
25m
Speed
4
5
6
7
8
9
10
11
12
Region 16


390
440
490
540
590
210
160
110
60
10
25m
Speed
4
5
6
7
8
9
10
11
12
Region 17


520
570
620
670
210
160
110
60
10
25m
Speed
4
5
6
7
8
9
10
11
12
Region 18

APPENDIX 1

MODELLING OF WIND SPEED VARIATION CAUSED BY CHANGE IN SURFACE ROUGHNESS AT COAST

Details of the NOABL programme for modelling of wind flow over complex terrain and the methodology developed to apply the model to resource estimation are given in previous reports [A1],[A2]. This methodology has been further refined to take into account the change in surface roughness that occurs at the coast. This section describes the method developed to model the effect of this change in roughness on wind speed, and its incorporation into the overall resource estimation methodology.

A.1 Method for single change in surface roughness

The most significant effects of surface roughness on wind speed occur near the coast, and are caused by the abrupt transition between the smooth sea and the much rougher land. Thus, on average, coastal wind speeds are notably higher than those well inland. No allowance was made for the coastal change in surface roughness in deriving the UK maps of wind speed and extractable energy shown in [A2]. Subsequently, however, the overall wind resource estimation methodology has been refined to allow for this effect, using the approach described below.

A literature review, and discussions with the Climatic Research Unit of the University of East Anglia and Dr Colin Wood of the Engineering Department of the University of Oxford, were undertaken to assess the methods available for modelling the variation in wind speed with surface roughness. Moore [A3] described a method for calculating winds at heights of between 10 and 100m from 900 mb wind data, which included an algorithm for modelling the transition from land to sea and vice versa. However, this approach has never been fully validated and lacks a generally accepted physical basis. In addition, the width of the coastal band of enhanced wind speeds predicted by this method is substantially wider than is considered realistic.

An alternative approach by Deaves and Harris, based on consideration of internal boundary layers, has been adopted by the Engineering Science Data Unit (ESDU), and is described in Appendix A of their Data Item 82026 "Strong winds in the Atmospheric Boundary Layer. Part 1 mean hourly wind speeds". This method has a more accepted physical basis than the Moore algorithm and is used for the prediction of the effects of wind speeds in the construction industry. The method has also been the subject of a number of wind-tunnel based validation studies. For these reasons, this method was adopted for the present study.

In the ESDU approach, the variation in wind speed with distance from a single change in surface roughness in governed by the following factors:

(a) Surface roughness of land (z_0)

(b) Height above ground level (h)

(c) Asymptotic land wind speed (v) at height h.

(d) Surface roughness of sea (z_{01}), which is calculated from z_0, given the asymptotic land wind speed

For the present work, z_0 was taken as 0.03 m - a value appropriate to smooth level terrain (e.g. flat grassland). A mean value for the asymptotic land wind speed at 10m height of 4.4 m/s was estimated using an average of the observed values from meteorological stations situated well inland. At heights of 25 and 45m, this corresponded to velocities of 5.1 and 5.6 m/s respectively, assuming an appropriate power-law vertical profile for wind speeds.

Figure A.1 shows the resulting predicted variations in wind speed downwind from a coastal change in surface roughness, for 10, 25 and 45m heights, derived using the above parameters. (These results have been validated by comparison with the modelled wind speeds derived by Dr Wood, Oxford University, who used an independent implementation of the ESDU method). As can be seen in Figure A.1, the wind speed over the sea at a height of 10m is predicted to be a factor 1.43 higher than the speed well inland. On land, the wind speed is predicted to initially decrease very rapidly with distance inland, reaching a value 1.15 higher than the asymptotic land wind speed at a distance of only 7 km from the coast. Thereafter, the variation of wind speed is less rapid, and at 200 km inland the modelled wind speed is still 1.01 higher than the asymptotic value. At heights of 25 and 45m, the wind speeds over the sea are higher than the corresponding asymptotic land values *at the same heights* by factors of 1.33 and 1.28, respectively. The variation of land wind speed, expressed as a factor relative to the asymptotic land value is, in the ESDU approach, independent of height. Thus, on Figure A.1, the three curves for heights of 10, 25 and 45m merge into a single curve over the land.

A.2 Multiple changes in surface roughness

For a particular wind direction, there are, in general, several land/sea and sea/land transitions for any line drawn across the whole UK. The basic ESDU approach for a single change in surface roughness therefore needed to be extended to the case of multiple changes in surface roughness. The procedure for doing this is described in the ESDU documentation, but it was found that the resulting modelled wind speeds were not fully consistent with those for a single change in surface roughness. This lack of consistency is illustrated in Figure A.2, which shows the variation in wind speed for (a) a single coastal sea/land boundary at a distance (x) of 20 km and (b) multiple sea/land and land/sea boundaries corresponding to two 10 km wide strips of sea centred at x=35 and x=75 km. For distances well-inland, the wind speed for the multiple boundary case (b) predicted by the standard ESDU approach is some 3 percent lower than the single boundary case (a). This is not apparently self-consistent, since the presence of two strips of sea should lead to *increased* not decreased wind speeds well inland, compared with the single boundary case. Furthermore, this effect becomes more pronounced for strips of sea narrower than 10 km.

This inconsistency was brought to the attention of ESDU, who agreed that the modelled wind speeds from multiple land/sea boundaries (especially narrow strips of sea) were somewhat uncertain at the level of around a few percent. The published ESDU method for multiple sea/land and land/sea boundaries has therefore been modified, to remove this inconsistency. This was achieved by constraining the modelled wind speeds from multiple boundaries to be never lower than the corresponding prediction from a single sea/land boundary situated at the position of the first (furthest upwind) boundary in the multiple boundary case. This modification is also illustrated in Figure A.2, which shows the modified and standard ESDU predictions for the multiple boundaries, together with the single boundary prediction.

A.3 Incorporation in resource estimation methodology

To incorporate modelling of the effect of the coast on wind speeds into the overall wind resource estimation methodology derived previously [A1],[A2], it was first necessary to generate maps of the whole UK showing solely the variation in wind speed caused by the change in surface roughness at the coast, for each of the 12 wind direction intervals. Since the wind speed variation was height dependent, it was also necessary to generate separate sets of 12 UK maps for each of three heights (10, 25 and 45m) included in the study. To generate these 36 UK maps, a binary (0/1) map was prepared from the UK terrain map, showing the land (value 1) and sea (value 0). For some wind directions, (e.g. westerly and southerly), Ireland and France cause some shadowing of the UK. Ireland and sections of northern France were therefore also included in this binary land/sea map.

The modified ESDU method, as described in Section A.2 above, was then applied, on a line by line basis, to the UK land/sea map, to generate maps of the UK showing the variation in wind speed caused by the corresponding changes in surface roughness for each height and wind direction. Different maps were generated for each wind direction and height above ground, making a total of 36 maps in total.

An example of such a map is given in Figure A.3, which shows the variation in UK wind speeds at 25m height for a westerly wind having an asymptotic land wind speed of 5.1m/s. The "streakiness" of this map is due to the application of the modified ESDU approach individually to each east/west line across the UK, independently of neighbouring lines. This one-dimensional modelling is somewhat simplistic, but alternative two-dimensional modelling methods would have been in-feasible to apply to an area as large as the whole UK. The effect of these "streaks" on the mean wind speeds, averaged over all wind directions, is in any case very small. To demonstrate this, a map was prepared (see Figure A.4) showing the variation in wind speed due to the coastal change in surface roughness, *averaged equally over all 12 wind directions.* This map shows negligible levels of streaking.

It should be emphasised that the map given in Fig. A.4, showing the effects of surface roughness averaged *equally* over all wind directions, was prepared for illustration purposes only. The technique developed to incorporate the correction for the coastal surface roughness change into the overall wind resource estimation methodology takes into account the *observed wind rose for each meteorological station individually,* as described below.

The UK maps of the variation in wind speed with distance from the coast for each wind direction and height above ground (36 maps in all) enabled modelling of this effect to be incorporated into the overall wind resource estimation methodology. For each of the 56 regions for which NOABL runs had been carried out, the UK maps showing the variation in wind speed due to the change in coastal surface roughness were used to derive 'speed-up' factors, relative to the meteorological station used for initialisation, at each point in the region. These coastal surface roughness factors were combined with the corresponding 'terrain' factors derived from the NOABL runs (which modelled the effect of terrain on wind speed) to find the final (instantaneous) modelled wind speed at each point in the region, relative to the initialisation station. Combination of these factors with the wind speed histograms for the initialisation station then enabled 10-year mean wind speeds to be found for each point in the modelled region.

A.4 Revised UK maps

The method used to derive integrated UK maps from the individual results of the modelling of the 56 regions, described in [A2], was repeated to provide UK maps of wind speed and extractable energy including the effects of terrain and coastal surface roughness. To obtain these integrated UK maps, an iterative procedure described in [A2], was first used to find scaling factors which were used to adjust the wind speeds and extractable energies for each region to match as closely as possible the values in neighbouring regions. The scaling factors used to obtain the integrated UK wind speed maps are given in Table 2.2 in the main body of this report. The values given in this table are similar to those used previously in the derivation of the integrated UK maps [A2].

As described in [A2], four different maps of extractable wind energy were also calculated for the following different assumptions concerning the wind turbine characteristics:

(a) MS3 WTG characteristic (25m hub-height; 33m rotor diameter)

(b) LS2 WTG (45 m hub-height; 50m rotor diameter)

(c) Two WTG characteristics based on scaled versions of the MS3 characteristic and locally optimised according to the mean wind speed in each 1 km square

(d) Four WTG characteristics based on scaled versions of the MS3 characteristic and locally optimised according to the mean wind speed in each 1 km square

A summary of the wind speed and extractable energy statistics for the current maps is given in Tables A.1 and Table A.2, for comparison with the previously derived maps (see Section A.5).

A.5 Comparison between UK maps with and without correction for coastal change in surface roughness

To assess the effect on the mean wind speed of the correction for the coastal change in surface roughness, the UK maps generated in the current phase have been compared with those derived previously [A2]. A comparison of the wind speed statistics for the whole UK is given in Tables A.1(a) and A.1(b). These show that the effects of the surface roughness correction on the mean wind speeds for the whole UK are small - the corrected wind speeds are slightly lower than the un-corrected values by between 0.15 and 0.1 m/s, depending on height above ground.

Towards the coast, there are, however, clearly larger differences between the corrected and un-corrected maps. To show these differences clearly, the un-corrected UK wind speed map at 25m was subtracted, point-by-point, from the 25m UK wind speed map, corrected for surface roughness. The resulting difference map is given in Figure A.5, and shows that as expected the corrected wind speeds near to the coast are higher than the un-corrected values. The maximum difference is about 1 m/s (15 percent of the overall mean wind speed at 25m height). It is the averaging of modelled wind speeds over *all* wind directions that has caused these differences to be significantly less than the modelled variation in wind speed for a *single* wind direction shown in Figure A.1 (in which the wind speed at the coast is some 33 percent higher than the speed well inland).

The averaging over wind directions is least significant on westerly facing peninsulas. so that the largest differences occur in areas such as Cornwall and the Welsh coast (see Fig. A.5). In contrast, the smallest coastal effects occur on relatively straight sections of the east coast, where the maximum differences are around 0.5 m/s.

It is also notable that in some inland areas, especially the highlands of Scotland, the predicted mean wind speeds after correction for the coastal surface roughness effect are *less* than those predicted without correction, by around 0.5 m/s. This is due to the location of the meteorological stations used for initialisation of the methodology. In the highland region of Scotland all but one of the stations were situated either on the coast or within a few km of it. In this case, the predicted wind speeds inland from these stations will be lower than those predicted in the absence of the correction for coastal surface roughness.

In inland areas of Southern England, the differences between the maps is less than those in the highlands of Scotland. This is consistent with the interpretation given above, since in the case of Southern England, the methodology was based a number of meteorological stations situated well inland.

APPENDIX REFERENCES

[A1] Burch, S. F. and Newton, K. 1988. Estimation of the UK wind energy resource using computer modelling techniques. Phase I: Optimisation of the methodology. ETSU WN 7053.

[A2] Burch, S. F., Makari, M., Newton, K., Ravenscroft, F. and Whittaker, J. 1991. Estimation of the UK wind energy resource using computer modelling techniques. Phase II: Application of the methodology. ETSU WN 7054.

[A3] Moore, D. J. 1982. 10 to 100m winds calculated from 900mb data. Proc. 4th BWEA Wind Energy Conference.

Table A.1(a) Wind speed statistics (10 year means in m/s) derived for whole UK, without correction for coastal change in surface roughness

	Height above ground level (m)		
	10	25	45
Minimum speed	0.3	0.8	1.4
Maximum speed	16.7	16.5	16.0
Mean speed	5.6	6.3	6.9
Standard deviation	1.2	1.2	1.2

Table A.1(b) Wind speed statistics (10 year means in m/s) derived for whole UK, with correction for coastal change in surface roughness

	Height above ground level (m)		
	10	25	45
Minimum speed	0.3	0.8	1.4
Maximum speed	16.5	16.3	15.8
Mean speed	5.45	6.22	6.8
Standard deviation	1.2	1.15	1.12

Table A.2(a) Extractable Wind Energy statistics (10 year means in kW) derived for whole UK, without correction for coastal change in surface roughness

	Wind turbine characteristics			
	Constant MS3	Optimised MS3 (2 categories)	Optimised MS3 (4 categories)	Constant LS2
Maximum power	1720	2760	3240	2360
Mean power	637	666	672	998
Standard deviation	223	306	321	282

Table A.2(b) Extractable Wind Energy statistics (10 year means in kW) derived for whole UK, with correction for coastal change in surface roughness

	Wind turbine characteristics			
	Constant MS3	Optimised MS3 (2 categories)	Optimised MS3 (4 categories)	Constant LS2
Maximum power	1700	2740	3320	2340
Mean power	612	636	641	966
Standard deviation	223	295	305	284

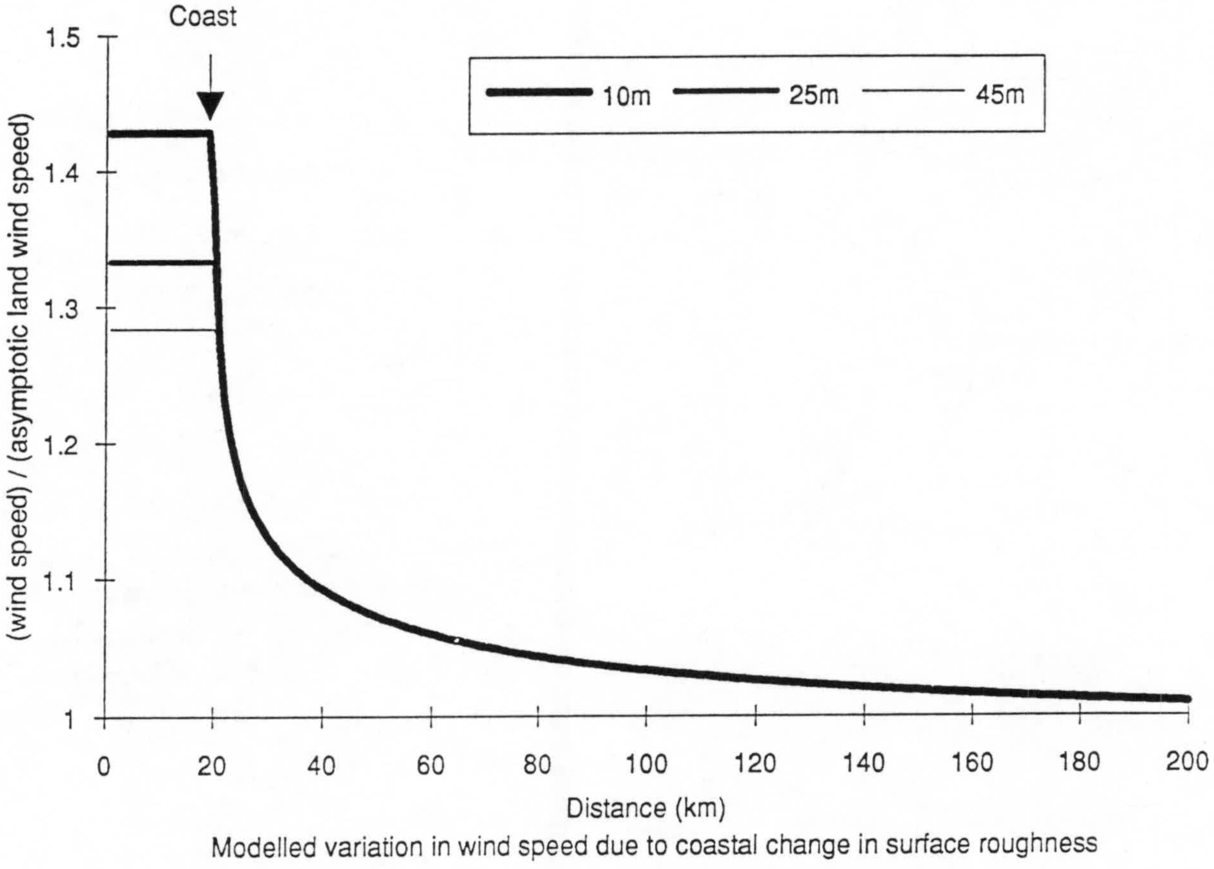


Figure A.1 Modelled variation in wind speed at 10m, 25m and 45m heights due to a single coastal change in surface roughness using the ESDU method.

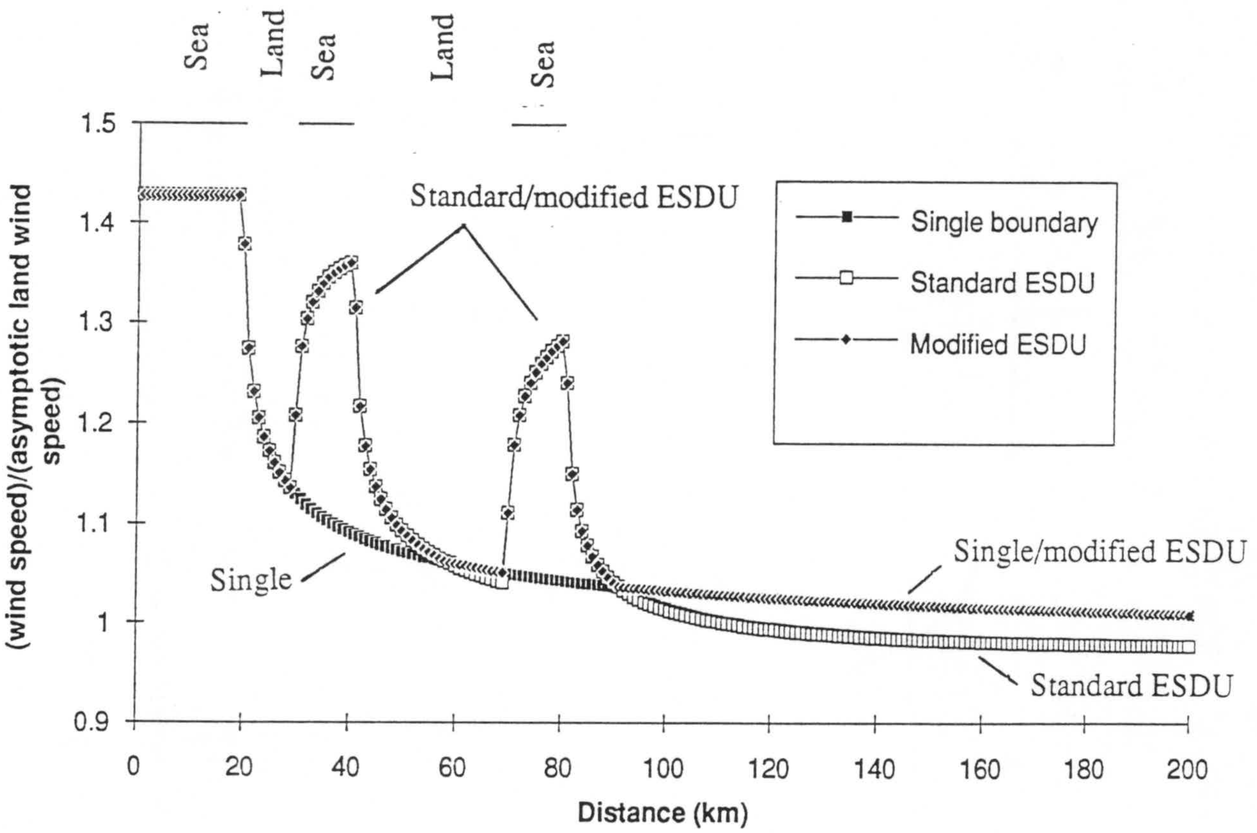


Figure A.2 Modelled variation in wind speed at 10m height due to single and multiple sea/land and land/sea boundaries using the standard ESDU and modified ESDU methods.

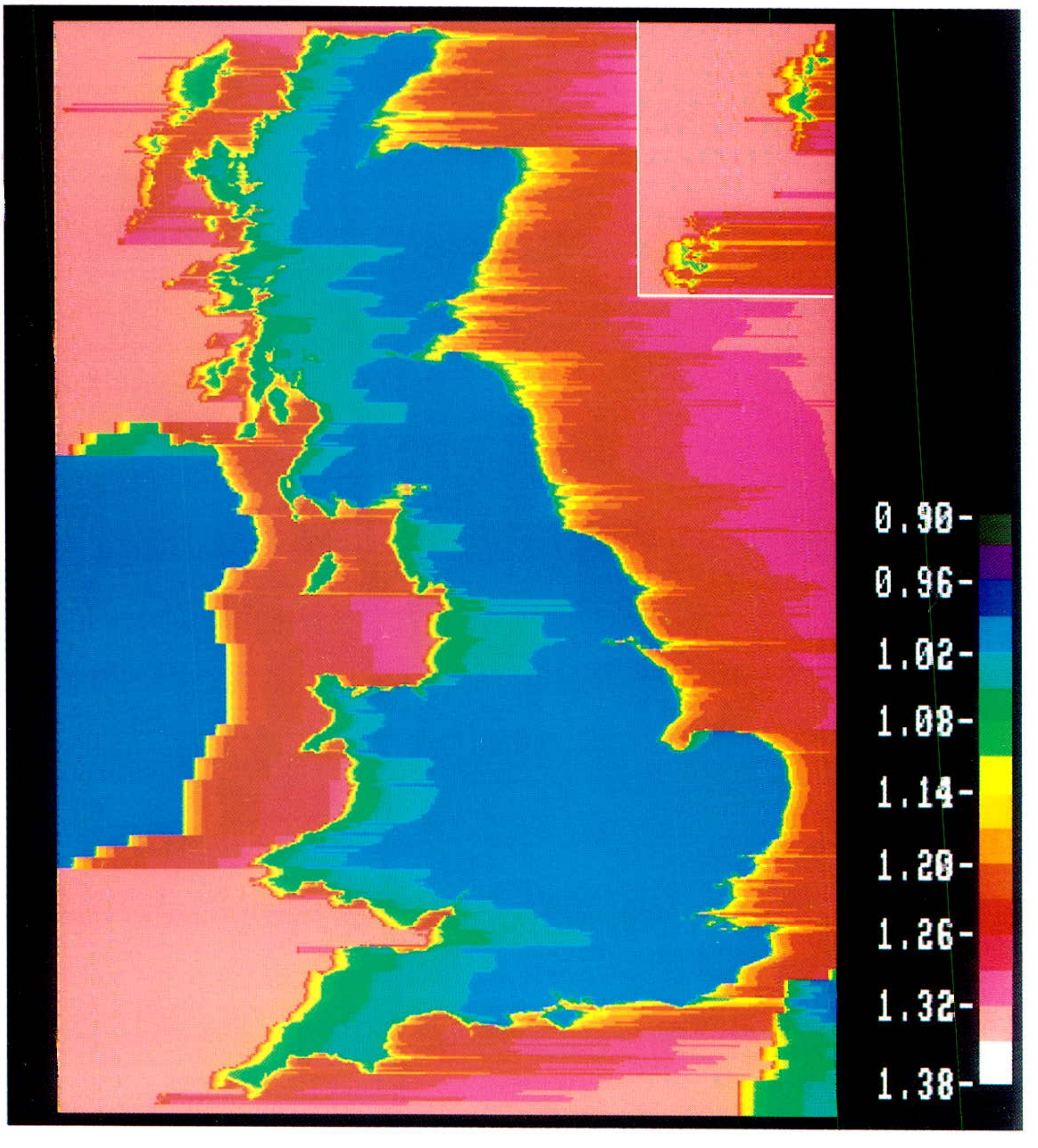


Figure A.3 Whole UK map showing predicted variation in 25m wind speed due *solely* to change in coastal surface roughness for a westerly wind direction Colour coding is used to show the wind speeds relative to the asymptotic land wind speed of 5.1m/s.

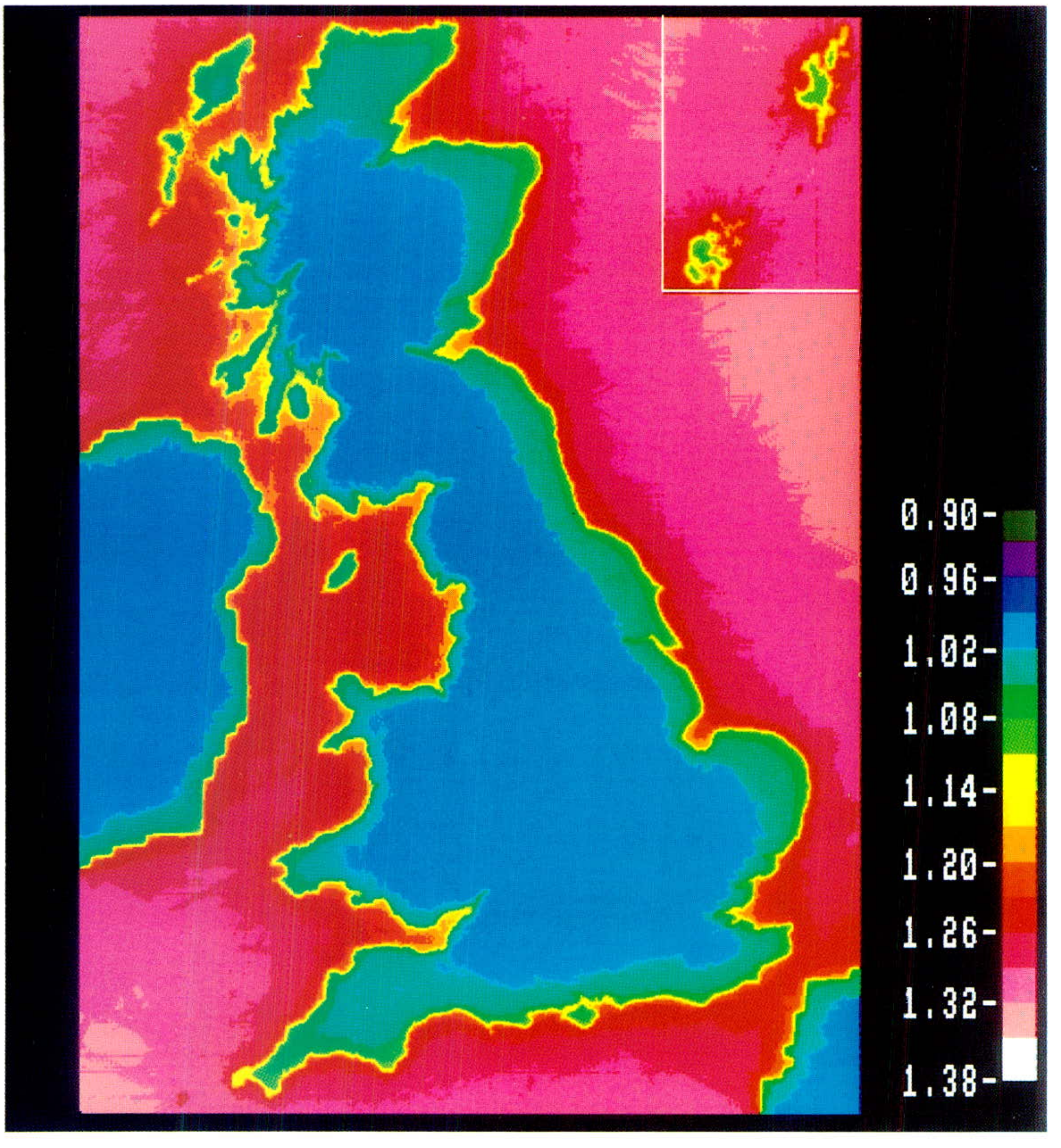


Figure A.4 Whole UK map showing predicted variation in 25m wind speed due *solely* to change in coastal surface roughness, equally averaged over all wind directions. Colour coding is used to show the wind speeds relative to the asymptotic land wind speed of 5.1m/s.

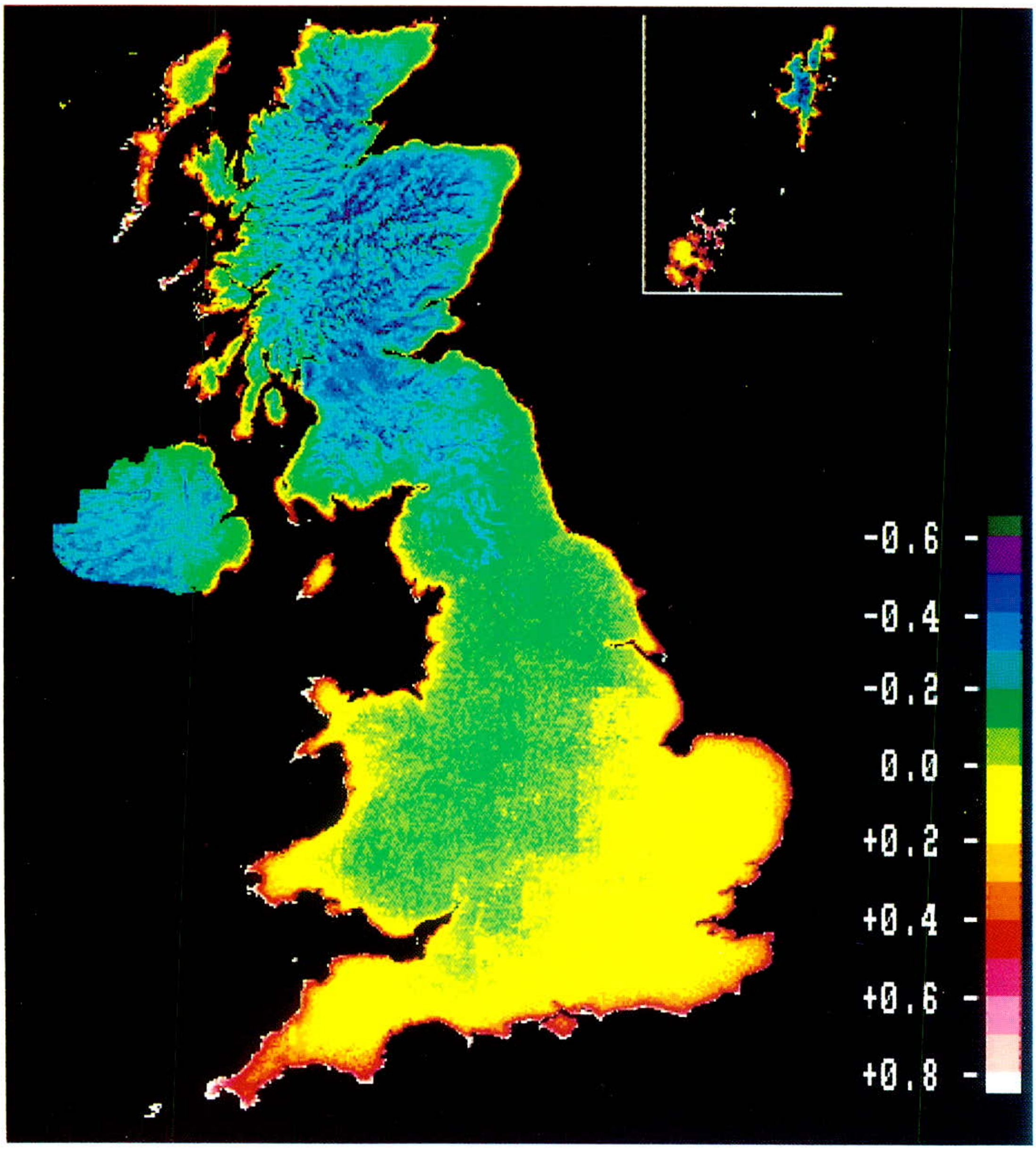


Figure A.5 UK map showing difference between predictions of 25m mean wind speeds with and without modelling of effect of change in surface roughness at the coast. Positive differences correspond to higher wind speeds after the full modelling.

APPENDIX 2

UK WIND SPEED DATA PACKAGE
(version 2.0, WSPEED2)

USER GUIDE

DESCRIPTION

The UK Wind Speed Data package provides the user with access to predictions of wind speeds over mainland Great Britain (GB) and Northern Ireland (NI) averaged over 10 years and to a resolution of 1 km^2, derived using the methodology summarised in this user manual. The wind speed information is available at heights 10, 25 and 45m above ground level and is arranged on the British Ordnance Survey (OS) Co-ordinate grid, with a size of 700 x 1300 km and the Irish OS Grid with a size of 310 x 300 km. The Irish OS grid has a different origin and is skewed at an angle to the OS grid for Great Britain, hence the need for two methods of accessing the data.

HARDWARE REQUIREMENTS

The package is designed for use on IBM PS/2s PC's or compatibles and can accommodate a wide range of graphics adapters. These being:

CGA
MCGA
EGA
VGA
Hercules
AT&T 400 line
IBM-8514

The package also requires a hard disk as each GB map file occupies ~912kb of disk space and each NI map occupies ~90kb. The total package occupies just over 3Mb.

DISK CONTENTS

The package is available on 4 high density 3.5" floppy disks. Each GB map file occupies one double sided, high density disk. All three NI map files together with the program file occupy the fourth disk,

The following files are supplied:

1) WSPEED2.EXE - Main Program
2) SPEED10.DAT - Data file for GB wind speeds at 10m AGL
3) SPEED25.DAT - Data file for GB wind speeds at 25m AGL
4) SPEED45.DAT - Data file for GB wind speeds at 45m AGL
5) SPEED10I.DAT - Data file for NI wind speeds at 10m AGL
6) SPEED25I.DAT - Data file for NI wind speeds at 25m AGL
7) SPEED45I.DAT - Data file for NI wind speeds at 45m AGL.

INSTALLATION

High Density Disk Drive

To install the package from High Density diskettes copy the files onto the hard disc. All the files should be placed in the **same** directory otherwise the program WSPEED2 will not be able read the map files.

RUNNING THE PROGRAM

To run the package type WSPEED2. The program is menu driven and will prompt the user to:

1) Select the geographic area. This can be either Great Britain or Northern Ireland.

2) Select the height above ground level (AGL) for the wind speed. This can be either 10, 25 or 45m.

3) Input the OS Co-ordinates - northing and easting to a resolution of 1km. For GB, Northing range = 0 - 1300, Easting range = 0 - 700, for NI, Northing range = 200 - 500, Easting range = 100 - 400.

The program will output estimated wind speeds at the requested height and OS co-ordinate.

Option keys:

E - Exits from the program. This key can be used at any time within the program

H - Outputs help menu for using the program

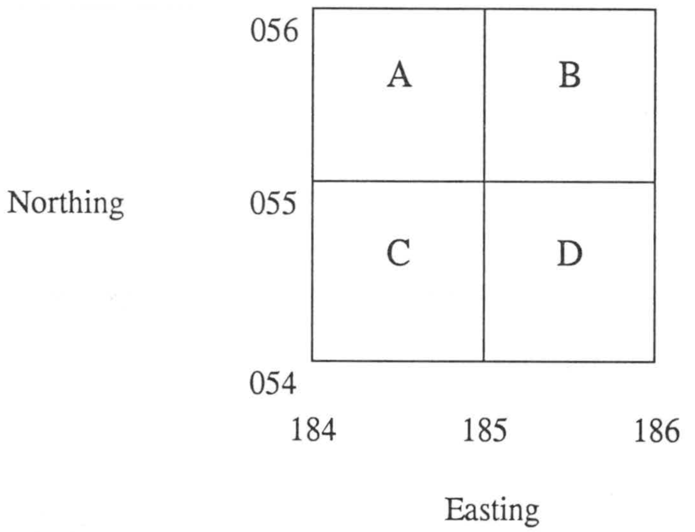
M - Returns to the menu for inputting a new height for wind speed information, or to the menu to select geographic area

R - Returns to co-ordinate input menu for re-entering OS co-ordinates at the same height.

G - Displays wind speeds in a grid format (3 x 3km) with the requested wind speed at the centre of the grid.

RELATING OS CO-ORDINATES TO THE CORRECT 1KM SQUARE

When using the wind speed package it is obviously important we get the data for the most appropriate 1km square. Always remember the grid reference, Easting followed by Northing, relates to the bottom left corner of the square containing the wind speed estimate. For example 184, 054 is the reference for square C (see below).



If the reference you are interested in is given to more accuracy than 1km it is generally **incorrect** to 'round up' the numbers. For example, 184.5, 054.5 is at the centre of square C, 184, 054, **not** in 185, 055, square B. The wind speed value for square C therefore provides the best estimate for the example.

If a position is very close to the junction of 2 squares it may be more helpful to take the average of the adjoining squares. For example for a site located at 184.5, 054.9, the average value of squares A and C may be a better guide than the value from C alone, even though the site is located in square C. A useful guide is the Grid option (key 'G') in the data retrieval program which gives the value of the km square whose co-ordinates you have entered and the eight surrounding squares. This is shown below:

5.6	5.5	5.5
6.0	**5.7**	5.2
6.2	5.9	5.1

where the value in **bold** is that for the square whose co-ordinates were given, in this case 250, 250 at 25m above ground level.

f:\Wind\grpadmin\fkb\WSD.doc